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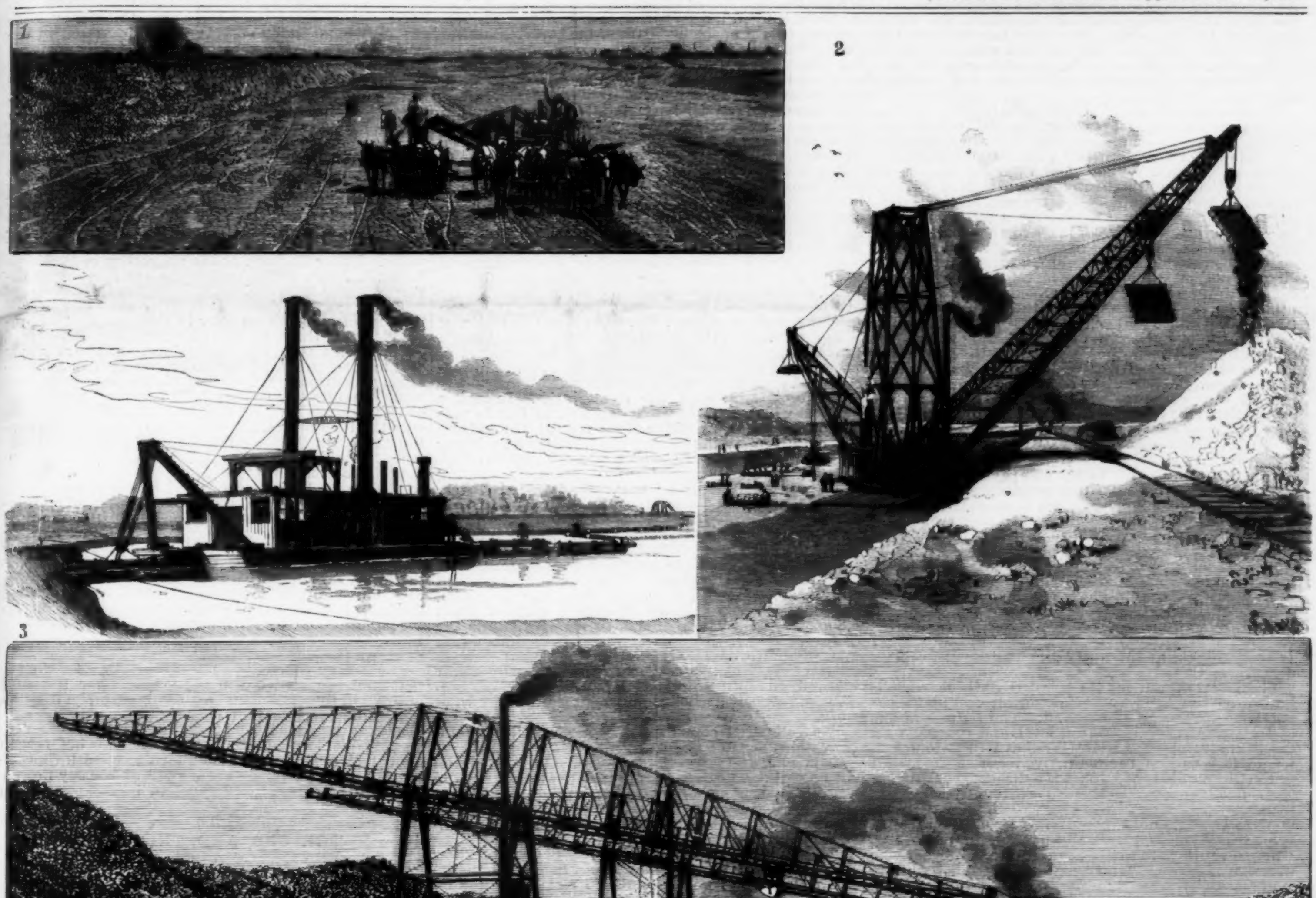

1. The New Era grader. 2. The high power steam derrick. 3. The Bates hydraulic dredge. 4. The Brown cantilevers. 5. Cable hoisting and transferring machinery.

THE CHICAGO DRAINAGE CANAL.

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THE headwaters of the Des Plaines River lie in Wisconsin, near Lake Michigan. The river runs to the south approximately parallel with the western shore of the lake, and, after it has reached the parallel of Chicago, trends to the southwest, and passing through Joliet, joins its waters with those of the Kankakee River, forming the Illinois River. The combined waters run through the channel of the Illinois River to the Mississippi, emptying into it a short distance above the mouth of the Missouri River. Through the city of Chicago winds the small stream called the Chicago River, a devious creek, with several branches. This enters into the lake. A distance of a little over ten miles intervenes between the lake shore and the Des Plaines River at Chicago, while between the Chicago River and Des Plaines River but two miles intervenes. At present much of the sewage of Chicago runs into the lake, threatening with contamination the water supply of the city, notwithstanding the fact that the intake of the water works is situated some miles out in the lake. Largely to avoid this contamination, the great drainage works which we describe and illustrate have been undertaken.

It will be seen that at Chicago there is a true divide, the waters on the east pouring into Lake Michigan and on the west reaching the Gulf of Mexico, through the channels of the Des Plaines, Illinois and Mississippi Rivers. Should the divide be pierced, the waters of Lake Michigan would run into the Gulf of Mexico, as well as into the Gulf of St Lawrence, and an internal waterway from the British Provinces through the St. Lawrence and the great lakes to the Gulf of Mexico would be created. At present work is being done on this connection, and if all goes well by 1896 the city of Chicago will have internal water communications with the Gulf of Mexico—communication to be utilized for the transportation of freight, as well as for the disposal of her sewage.

While the operation of merely effecting water communication between the Des Plaines River and the lake by the Chicago River would be comparatively a small affair, the necessities of the case are such as to involve very extensive work and the excavation of one of the great canals of the world. The Des Plaines River in some seasons runs almost dry, so that its entire flow could pass through a six inch pipe; at other times what is described as a majestic flow of water, flooding the whole ofits valley and passing through it at the rate of 800,000 cubic feet per minute. In order to secure the construction of a canal through the valley of Des Plaines River, a new channel in places has been made for the river at an outlay of nearly $1,000,000. This alone involved the excavation of thirteen miles of new river channel, parallel with the main drainage channel, and nineteen miles of levee had to be used to keep the water of the Des Plaines watershed out of the canal. The latter has to be restricted as far as possible to the one function, the conveying of sewage of Chicago diluted more or less with the waters of Lake Michigan, to the lower Des Plaines River, near Joliet.

The levels of the canal are referred to as what is known as the Chicago Datum, 579·61 feet above the sea level of Sandy Hook, N. J. The bottom of the canal begins 25 feet below this level, and running on a down grade, follows the Des Plaines Valley to Joliet, where it is to join the main river. From the mouth of the Chicago River to Joliet is a distance of 35 miles. This involves considerable excavation, reaching in places a depth of nearly fifty feet. The present aspect of the works is quite impressive. At places in the rock the excavation is practically completed, while elsewhere operations in earth, peat, and rock are actively in progress. The general course of the canal is slightly sinuous, and the parts under contract between Lockport and Chicago are divided into 29 sections, each section approximately one mile in length. The grade to be followed is so steep—about forty-two feet in four miles, at the steepest part—that a very strong current would be established. For reducing the flow accordingly, controlling works are to be introduced at the western end for keeping back the flow. As it is proposed to use the canal for barges, some of which will be 500 to 1,000 tons capacity, provision will be made for passing around the dams by means of locks.

The great freshets to which the Des Plaines River is exposed brings out the question of supplying an adequate outlet for water. Accordingly, a spillway is provided at the head of the river works proper, or "river diversion," as it is called, which are to be so proportioned that when the flow exceeds 300,000 cubic feet per minute, the excess will flow over the spillway and toward Chicago, finally going into the lake.

The river diversion channel on the bottom is 200 feet wide; side slopes, 1½ to 1. Its general grade is 0·12 per 1,000 feet. The canal proper varies in width, its maximum section providing for a total flow of 600,000 cubic feet per minute, enough for the sewage of a population of 3,000,000. This is the legal capacity of the canal. In softer ground, however, where dredging at any time will be applicable, the channel is reduced to about one half this capacity. The idea is that, as the population increases, the narrow portions can be dredged out.

The portion of the canal now being constructed is in the hands of numerous contractors, and for executing the work these contractors have selected their own plant, and the consequence is that the most varied class of machinery is employed on the works. Our illustrations give examples of the more striking and original types. Fig. 1 shows the direct application of horse power for excavation in the New Era grader. This great machine, drawn by its team of eight draught animals, cuts away the soil and delivers it one side to a spout by belt conveyor. At the end of the spout team after team draws its wagon to receive the spoil, the work going on practically without break. It has been applied for removing the upper seven feet of earth on some sections.

Fig. 2 shows one of the high power derricks, whose operations are obvious. With its long booms and rotary movement it transports the material from the center of the canal to the banks, perpetually turning about on its own axis. These have not proved as economical as anticipated.

Hydraulic dredging has its exponent in the Bates hydraulic dredge, shown in Fig. 3, used for cutting away peat and similar materials. From the booms in front of the dredge is suspended what may be called a giant milling machine—a wheel with blades rotating on a horizontal axis and cutting through the turf to right and left as the dredge is moved and fed to its work. From the vicinity of the cutting wheel a pipe runs to the dredge, connected to a rotary pump, by which the material is pumped through the long pipe seen running astern floated on pontoons, and which may deliver the soil 3,000 or more feet away. These dredges average a rate of 100,000 cubic yards per month, which, as it includes delivery as well as removal, is a most remarkable result.

Fig. 4 shows one of the most striking machines and an impressive view of the work. Here are shown two of the giant Brown cantilever machines, working in a rock section. The sides, nearly vertical, have been cut in the solid rock by a channeling machine of which 57 have been employed at one time on the canal. On the bank the cantilevers travel on rails. The sloping trusses provide an inclined track for carrying up the loaded buckets and delivering their contents far up on the bank. The great trusses are 342 feet long and each machine disposes of 600 cubic yards per day, principally of rock blasted out by dynamite. One of these machines can deliver material from the far side of the canal over a mountain of debris 90 feet high. They are considered to represent the highest degree of efficiency.

Fig. 5 shows work on a rock section executed by cable conveyors. From trestle work abutments moving on tracks, cables are carried clear across the cut and are used for conveying the material to the side. As improved since their introduction, they compare with the cantilevers. Their original cost is about one-half that of the cantilevers. In the background of this cut can be seen the channeling machine at work, to whose operations are due the great regularity of the side walls. These views present some of the principal machines used, but cannot give an idea of the grand scale of the operations. The fact that seven tons of dynamite are used in a day in the removal of 14,000 cubic yards of rock gives an idea of the unprecedented magnitude of the operations.

The cross section of the canal varies. In rock a uniform width of 162 feet to a depth of 22 feet is provided for; in earth a width of 202 feet at the bottom is provided for, of the same depth. This gives a larger cross section of prism than that of any canal in existence. The nearest approach to it among existing canals is the North Sea Canal, and of canals in existence or proposed the Nicaragua Canal comes the closest.

The work is under the charge of the Trustees of the Sanitary District of Chicago. The State of Illinois, by statute passed in 1889, provided for the incorporation of sanitary districts. The sanitary district of Chicago applies to all the city north of Eighty-seventh Street, together with some 43 square miles of Cook County. A population of about 1,400 000 inhabits the district. The trustees are elected by popular vote and are quite distinct from the municipal government of Chicago. They have the right to collect taxes to definite amounts stated in the law, and they can also issue bonds for the prosecution of their work.

The estimated cost for the work is $21,799,293.82. Operations began on September 3, 1892. November 1, 1896, is set as the probable date of completion of the entire work. The cutting represents two-thirds of the cost of creating a channel from Chicago to the Mississippi. Federal work on the Illinois and Mississippi Rivers is needed to complete the waterway from Chicago to the Gulf of Mexico.

Chicago datum designates the level of the low water of Lake Michigan in 1847. At Robey Street, where the canal begins, the bottom is 24·488 feet below datum. The entire descent would be sufficient to send a very rapid current through it, but at Lockport controlling works are established, consisting of gates or movable dams, by which the flow of water from the canal into the Des Plaines River beyond it is controlled. Thus the course of the Chicago River, whose waters now run to the lake, will be reversed; the lake will in the future run into the Chicago River and down the canal, and the outflow will be regulated by a dam at Lockport in the distance.

The Des Plaines River, whose stream is subject to the widest fluctuation, has also been taken care of. Accordingly, diversion works, as they are termed, are established, one of our smaller views showing the work in progress upon them, to keep the water out of the canal. Thirteen miles of new river channel were excavated parallel with the main drainage canal, nineteen miles of levee were built between river and canal for the same purpose, while at the head of the river diversion a spillway is to be built for letting surplus water run back into the lake, as arrangements have not yet been made to carry the entire flow of the river with that of the canal to the city of Joliet below Lockport. It will thus be seen how very perfect the whole system is.

Looking at the bird's eye view, the terminus of the canal marks Lockport. Below Lockport the sinuous river can be traced to Joliet. This portion is a relatively steep declivity, involving a fall of some forty-two feet in a distance of four and one-third miles. Lockport, therefore, is the critical point; the raising or lowering of the control gate a few inches means an immense difference to the flow through the canal. Up to the limit of the canal's capacity the level of the great lakes rests in the hands of the engineer.

It is not only as a drainage canal that the work is being prosecuted. The Chicago people fondly hope that it will eventually be a fully developed ship canal, and some believe it possible that communication with the ocean may be made by it. Our view of the canal as completed, with a railroad on the bank, the steamship and steam barge running through it, gives an idea of what it will be like when finished. The other view shows operations incident to the excavation.

THE EFFECTS OF THE CANAL ON THE COMMERCE OF THE LAKES.

THE Chicago drainage canal is an undertaking that bids fair to create a stir in at least half a dozen large divisions of the world's activity. Both science and mere economics are viewing the engineering operations between the Chicago and the Des Plaines Rivers, which undertake to neutralize the watershed between the Great Lakes and the Mississippi River, each with an interest peculiar to itself. The plan is, by means of the canal, to divert such an amount of the water of Lake Michigan into the Mississippi as to give the Chicago River a backward current sufficient to carry off the sewage of Chicago, the fall toward the lake not being sufficient to give the river any current of account and making it little more than a big slackwater sewer, a nuisance and an eyesore from every standpoint.

When the work was undertaken the city asked no questions. It arranged to take a certain definite amount of water out of Lake Michigan without so much as inquiring whether there were any rights infringed upon by the transaction. For awhile the marine interests looked on without taking any steps to protect its interests. Chicago writers and engineers for the most part assumed that there would be no lowering of the level of the lakes, but in this they were so generally opposed by engineers not interested in the city's wants that the government at length appointed a board of three engineers to inquire into the matter. The board consists of General Poe, stationed at Detroit, Major Ruffner, at Buffalo, and Captain Marshall, at Chicago. The time of meeting has not been set, but is expected to be during the present summer.

The estimates of the amount that the canal will lower the lake level vary from a matter of three inches to about nine inches. Finding that this limit was likely to cover the actual fact and finding, curiously enough, that there are no data by which anything short of the actual experiment itself is sufficient to settle the question, there was consequently a deep interest in the result to navigation from the loss of these depths of water. Major Ruffner, at the suggestion of President Frank S. Firth, of the Anchor line, the lake line of the Pennsylvania Railroad, asked Secretary C. H. Keep, of the Lake Carriers' Association, to make an estimate of the loss of carrying capacity to the lake fleet at lowered levels of three, six and nine inches.

The work was very carefully done, and the accuracy of it in a general way is not to be doubted, for an actual consideration was made of all the lake craft that would be affected by the fall of water. Mr. Keep's conclusions are little short of startling. Without going over the long report, the following quotation will give the gist of it: "A lowering of the lake levels by three inches would produce a diminution of the carrying capacity to the lake fleet in a season amounting to 1,142,370 tons. A lowering by six inches would diminish the carrying capacity 2,284,740 tons. And a lowering of the lake levels amounting to nine inches would diminish the carrying capacity 3,427,110 tons. Turning these results into dollars and cents, and estimating the earnings of lake vessels at an average of 50 cents per ton of cargo carried, over and above cost of loading and unloading, a lowering of three inches would diminish the earnings of the fleet in a single year $571,185; a lowering of six inches would diminish the earnings $1,142,370; and a lowering of nine inches would diminish the earnings $1,713,555."

The report concludes with calling attention to the fact that the tendency of the new tonnage is almost entirely in the direction of deeper draught, so that the loss would increase year by year. Major Ruffner regards the report as one of the most important documents of its kind, and says that the showing is such that the lake interests could afford to furnish Chicago a plant for disposing of her sewage by the dry process rather than to allow the canal to be completed and used.

THE OLD AND THE NEW.*

By ROBERT ALLISON, Port Carbon, Pa., Member of the Society.

AT a reunion held at the house in New York of the American Society of Mechanical Engineers, in April, 1893, one of the speakers† made some remarks in reply to the presentation to the society of a portrait of the late Mr. Harrison, of locomotive fame. In his remarks he stated that the mechanics who constructed the first locomotives, with the tools and appliances then available deserved more credit than the mechanics who build the splendid machines of the present day. Having this in mind, I thought it might interest some of the younger members of the society to learn of the difficulties and trials of the old time machinists, of which the writer was one.

It is now about fifty-one years since I first entered a machine shop as an apprentice, in 1844, my first experience being in the shops of Haywood & Snyder, at Pottsville, Pa. The shops were considered as well equipped as any in the interior of the State; there were two or three slide lathes (not screw cutting) in the shop, but most of the turned work was done with the slide rest, and all the small turning was done with hand tools. There was one planing machine in the shop, the table being pulled back and forth with a common one-half inch chain. I recollect that this chain would break frequently, sometimes two or three times a day; so a number of open links were kept on hand to make quick repairs. The cross feed was automatic; all other feed directions were by hand. Those of you who have had any experience in a modern shop will appreciate the difference between those crude machines and the machines now in use.

The work done in the shops was principally steam engines, and, notwithstanding the poor facilities, many good engines were turned out, some of which are in use to-day.

After working in the Pottsville shops about one year, I was sent to Danville, to the branch shops in that place, my masters having taken the contract to make the machinery for the Montour Rolling Mills, the first mills in the United States to make "T" rails. The mills were constructed under the supervision of Mr. Henry Brevoort—some of you may remember him, as he was located in New York after leaving the Montour Mills. I shall always have pleasant recollections of Mr. Brevoort, as he took special interest in me and my

* Presented at the Detroit meeting (June, 1895) of the American Society of Mechanical Engineers, and forming part of Volume XVI of the Transactions.

† Mr. J. F. Holloway, of New York, ex-president, received in the name of the Society the oil portrait of Mr. Joseph Harrison, the gift of the Society from his widow, through the influence of his nephew, Mr. Henry Harrison Suplee.

work, and would frequently insist on certain pieces of work being placed in my hands for execution; for, while I was only an apprentice, he thought that I did better than some journeymen.

The shop was equipped with two large lathes, thirty-six inch swing, mounted on heavy wooden shears, and the turning was done with heavy slide rests; there were also three smaller lathes on wooden shears, with slide rests; and two hand lathes, operated exclusively with hand tools; also one drill press and one screw cutting machine—this constituted the whole plant.

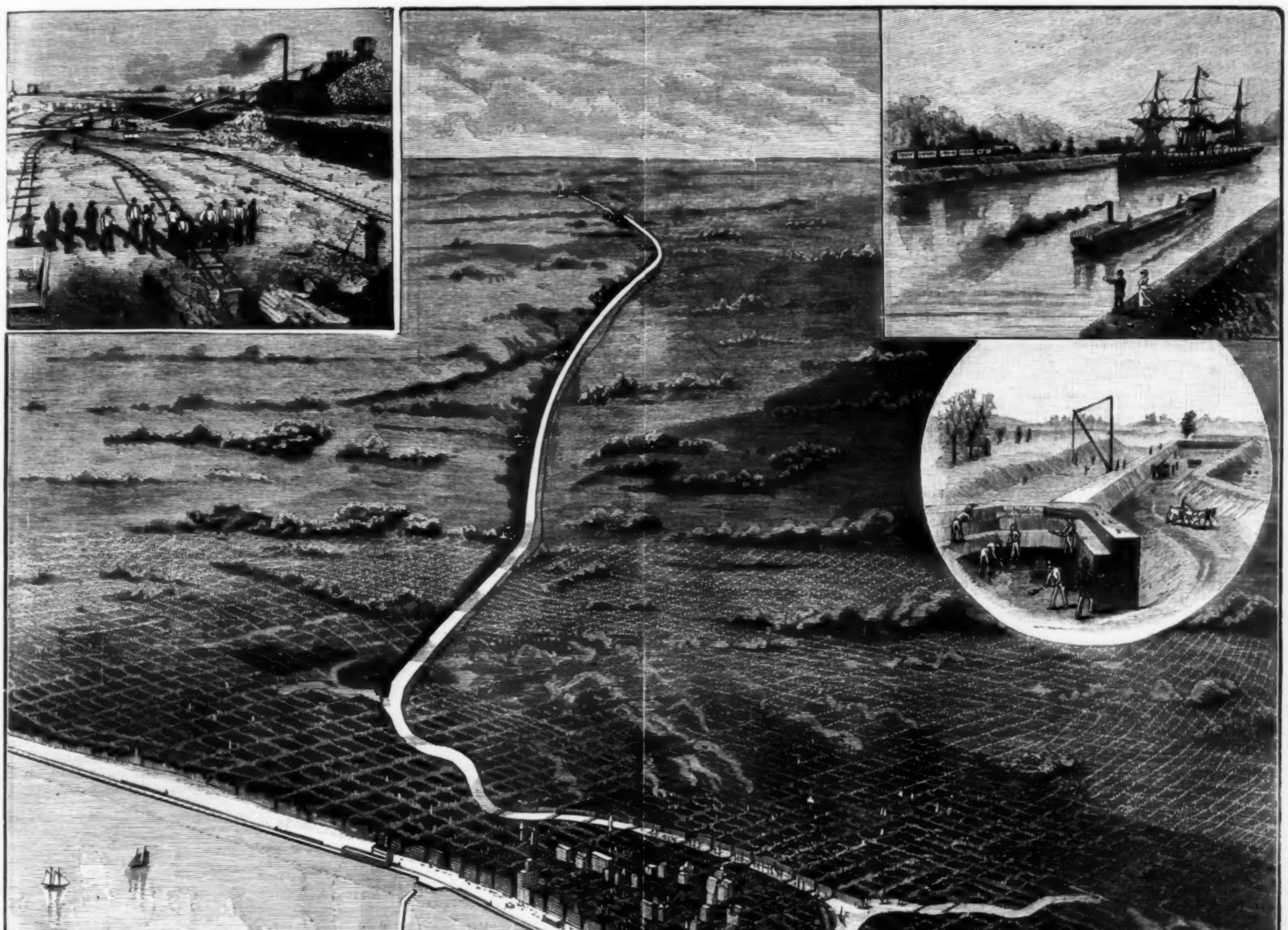
The whole of the rolling mills proper were built in this shop, the engines being built in the Pottsville shops. In the early days of rolling mills, you remember, the engines were made long stroke, usually six feet, and the rolls were driven with gearing so as to get up the proper speed, the piston speed of the engines being about three hundred feet, the gear wheels being large in diameter; there were no facilities for boring the hubs, and they had to be keyed on the shaft with six or eight keys. This necessitated much chipping of key seats.

Shafts were all made of cast iron of large diameter, with bosses in proper places for wheels; the bosses were turned off, and then eight flat places were chipped and filed true for keys, the wheel hubs were cored out about one and one-half inches larger than the shafts, and eight key seats cut of proper width and taper, according to the size of the shaft; then the wheel was staked on the shaft with four short wedges on each side, leaving four of the key seats clear. It required considerable skill to get the wheels true on the shafts, and but few were able to make a good job. After the wheels were staked on true, four of the keys were fitted and driven home, the stake wedges removed, and the other four keys fitted. Large cranks were fitted to shafts in the same way. The whole operation required a great deal of skill, and unless a man was an expert chipper and filer he would make very slow progress. The turning of large shafts was slow and tedious; the writer remembers having a cast iron shaft ten inches diameter and about ten feet long being given to him to turn on a hand lathe, with hand tools, the slide rests all being in use, the tools used being hook tools "V" and round nose, button and spike heads. Just imagine the feelings of a machinist of the present day if confronted with a job of that kind! I also remember another job that almost made me sick. This was forty set screws, one and three-quarters inch diameter, about four inches long; the iron was seamy and hard, they had to be turned from point to head and thread chased the whole length. You can hardly imagine the condition of mind I was in by the time I finished the last screw; and I think that if there had been about five more in the lot, the country would have been obliged to get along without my services as a machinist, as I would have quit the business in disgust.

The chasing of screws by hand was one of the things we all had to learn. Starting the thread properly required considerable skill; drunken threads were rather common, and subjected the producers to considerable ridicule in the shop. All plane surfaces had to be chipped and filed, no matter what size, and good chippers were always in demand. Engine guides were made round because shops had no planers to plane them if made flat; and when the first flat guides were made, they had to be chipped and filed; connecting rod stubs were fitted the same way. Notwithstanding all these drawbacks, very good work was turned out, some of which will compare favorably with the work of the present day. We still have some old fogy machinists who claim that the work of the present day does not compare with old-time work, when accuracy and finish depended on the skill of the workman rather than on the accuracy and automatic operation of modern machinists' tools. The writer has had considerable experience in old-time methods and with modern tools, and has no hesitancy in saying that the work of the present day is far superior to what was turned out by the old methods; but, as Mr. Holloway said in his remarks, the wonder is how such good work was turned out with the limited appliances at hand, and the mechanics of fifty years ago deserve more credit for their productions than those of the present day.

It may interest some of you to have a short account of how a steam engine was produced fifty years ago in the shops where the writer learned his trade. First a large drawing board was prepared, large enough to make a plan and side elevation, full size. Engines all being made very long stroke, the drawing boards were quite large; an engine of fourteen inches diameter, forty-eight inch stroke, taking a board about six by twenty feet. The engine was plotted down, lines chalked and leaded; patterns were then made to correspond to the drawings, castings were made and fitted, but connecting rod, piston rod, valve rods, etc., were left till the cylinder, guides and pillow block were fitted on bed plate. Measurements were then taken for the different rods, and the rods made the proper length to fit. No two engines were exactly alike; variations in shrinkage and fitting were adjusted in the length of the rods. Generally, after the first engine was made, the drawings were planed out, so that the drawing board could be used for another size. This destroyed the record of sizes, but as all rods were measured for each particular engine, this did not interrupt the work of construction. I need not refer to the present methods in this line, as you are all familiar with them. To-day almost every part of an engine, or other machine, could be made in different shops, widely separated, and then assembled into a complete machine without a hitch. This would have been impossible under the old plan. Taking all the disadvantages into consideration, the wonder is that the mechanics of fifty years ago could turn out as good machines as they did.

President Davis, of the society, remembering the equipment of the Haywood & Snyder shops when he took charge of them, might contribute some interesting material; but at that time they were much improved over what they were when the writer served his apprenticeship in them. I trust he may be able to add something of interest to what I have said on this subject. We would be glad also to hear from those who labored in other lines and in different places.



BIRD'S EYE VIEW OF CHICAGO AND THE DRAINAGE CANAL

DISCUSSION.

Mr. Samuel Webber.—When I first went to Lowell, in 1841, I made the acquaintance of old John Dummer, who had built all the wooden waterwheels then in use there, and who came from the family from which "Dummer Academy," at Byfield, Mass., was named. Afterward, in 1847, I worked a year under Captain Phinehas Stevens, who built the "Bay State Mills" at Lawrence, Mass., and put in the last large "breast wheels" used in New England, so far as I know. The old Masonic emblems of the "level, square and compass" were the principal apparatus used, and the "broad ax" was one of the most familiar and useful tools. The old "surveyor's compass" was used in laying out the ground, and the "level" was practically as good then as now.

"Lathes" for turning wooden columns, shafts, etc.,

had long timber beds, and were often set up in a convenient sawmill, and the tool, held in both hands, had a long wooden handle which would reach back under the arm. Large curved work was usually "scribed out" on the attic floor of the carpenter's shop, and the "cooper's adz" and "draw-knife" were also important tools in working out these curves. Water-wheel shafts were usually made of wood with cast-iron "gudgeons," and cast iron in short lengths was generally used for shafts. These were usually square, but I remember when the late E. A. Straw, of Manchester, N. H., who had been sent to England to examine mechanical matters, came home and fitted up one of the "Stark Mills," in Manchester, with hollow cast-iron shafts, which were round. These were afterward taken out and solid wrought iron shafts put in their place, which gave the mill an enormous load of unnecessary dead weight.

Mr. Straw had been brought up by Mr. Boyden, of turbine celebrity, and had commenced engineering on the Nashua and Lowell Railroad.

The large pulleys of those days were all made of wood, on cast-iron hubs and spiders, a form to which we are now returning.

Leather belts were made on the spot as wanted. There was no such thing as a ready-made belt in the market. All the mills and shops bought their leather from the tanners, by the side, and each establishment had its "belt shop," where the hides were cut up and stretched, and afterward the edges "trued" and cemented, stitched, or "pegged" together, wooden shoe-pegs being often used for this purpose. Machine tools were few to those of the present day. The iron planer had just been introduced, and the engine lathe was still a novelty. The first tool I ever worked on had V ways, which had been chipped by hand and "draw-filed" to a straight edge!

Donkey engines were unknown, and all heavy lifting was done by animal muscle applied to levers, or ropes and pulleys.

Dams were usually built of timber, filled in with rough stone, planked on the upper side, and loaded with gravel, and were a prominent feature in the work of the millwright, as were also the flumes or feeders for conveying the water to the wheels, which were square, and made of planks "keyed up" in timber frames.

Large pipe, either of cast or wrought iron, was unknown. When turbines came into use, the feeders were often made round, of wooden staves, hooped with iron, like a barrel.

Mr. William E. Worthen.—It is my impression that not only the "large pulleys were built on cast-iron spiders," but that all pulleys were built up in this way in the early days, making a drum of uniform diameter for nearly the whole length of shaft, and that the shafts were of cast iron; and even if of wrought iron, nothing was turned except the journals. There was an advantage in these long drums, that the machines which they drove could be readily shifted laterally, and larger drums could be readily constructed on them by board laggings when necessary for a change of speed on the machines. The ends of these drums were closed to prevent dust from getting into the central space, and these ends were painted a dark green, which was a favorite color for the frames of machines, which were at that time invariably of wood, usually ash. All machinery of the Lowell Manufacturing Company was made after the designs of Paul Moody, at Waltham originally, afterward at Lowell, and no change was allowed to be made by any one except with his approval. At the shop there were foremen of the different rooms appropriated to the different machines, to whom the work was let by contract.

The machine shop furnished, set up and started the machinery of the mills. The superintendents of the mills were not mechanics or manufacturers. The machine shops furnished machines and were responsible for their working. No alteration was allowed, and the superintendent had charge of the work people. They compared the results of the same class of work in the different rooms of their own and other mills, took charge of the boarding-house keepers and the morals of the operators. Under these regulations the mills were a success; but in 1831 Mr. Moody died. There were now many other cotton mills in operation and throughout the country, and soon the directors of the companies were alive to the new ideas, that there were other machines than their own, and which were improvements in the quantity or quality of the products.

I recollect when the first Whitworth planer was introduced at the machine shop, and went to see it at work, and could appreciate the amount of chipping that it would save. Early in the forties, the Lowell Manufacturing Company took a contract of the Reading Railroad for the construction of freight cars, of which the pedestals were made of a single plate of wrought iron and the jaws punched out by a hydraulic press.

George W. Whistler came to supply Mr. Moody's place, and locomotives were undertaken at the shop, and I had the advantage of seeing the great trouble and trials in working out new designs much larger than the English ones.

Colonel Webber refers to old John Dummer—he was about fifty at the time. As a millwright, he was the best I ever knew. His designs were good; he took charge of his work personally, never talked but little to his men; in fact, never to any one unless it was necessary, and his work was joiner work. He would never loan on interest, as he called it usury.

He built the first wheels at Lowell in 1822, and none of them were, I think, ever renewed. The entire fall was at first thirty feet, which was used as a whole at the Merrimac Mills, but at the other mills in divided falls of seventeen and thirteen feet, as the power could be thus distributed, and sales of real estate extended. The wheels were of one type, wooden breast wheels with cast iron shaft, in two pieces, coupled together at the center, by a socketed hub; on the journal ends there were large flanges with sockets. Three sets of arms were fitted to these sockets, and braced from the ends to the central arm. The gates were horizontal, sliding over apertures leading vertically down the center of the buckets, usually in three tiers, the lower one being detached except in cases of low water.

Mr. Dummer continued to build these wheels till the introduction of Boyden's turbines, and, although the first ones had wooden flumes, he never took kindly to them or had much confidence in the results and gave up his business as a millwright and removed into the country.

As the construction of turbines with the precision required by Boyden was then beyond the capacity of most of the mechanics of that time, Mr. Boyden attended to it personally.

In testing the wheel every observation was made independently by two parties, nor was there any connection between other parties of the test, those at the weir with those at the wheel, and Mr. Boyden made separate observations of his own, with the notes of continuous observations. Thus complete, the percentage of effects at different speeds and openings of gate could be readily separated and calculated.

Mr. Boyden came of a remarkable family, strong generally, physically and mentally, of which Seth Boyden was another. In addition to his mental activity, he had wonderful persistence; without anything but a common school education, he made his calculations and designs with confidence, and the results were what was looked for, but not in money to him.

In his design and construction of the turbines for the Atlantic Mills, of Lawrence, Mass., there was so much delay in construction that the company could not afford them for as long a test as he wished, and to determine the percentage of effect, which was a factor in his remuneration, a commission was appointed of Judge Parker, Prof. Benjamin Peirce and Mr. James B. Francis, who returned a verdict of considerable over ninety per cent. The factors of the calculation were head of water, speed of wheel, drawings of guides and wheel, and velocity of issue with its direction, that is as far as I recollect. Mr. Boyden made his calculation by arithmetic approximations, but as Mr. Francis told me Prof. Peirce said that the results were correct, but showed that the work of months by Mr. Boyden, with his usual checks by different calculators, could have been resolved in minutes by use of calculus.

At the Nashua Mills he persisted for months to find out the reason for the smaller percentage than what he expected, keeping his assistants at work during mill hours in the week and also on Sundays, and to their remonstrance that it had got to be monotonous, changed the dinner time of Sunday from half past twelve to one P. M.

He found the why—it was the reduction of the depth of the guides about two inches.

It has been a pleasure for me to look back and see what I could recollect, and if it were like a civil service examination, I could answer interrogatories better.

Mr. Olin Scott.—The millwright of fifty years ago was the mechanical evolution of the preceding ages from the times of Archimedes, and was supposed to know everything pertaining to machinery and mills, from a watch movement to a fifty foot overshot water wheel.

Before describing anything pertaining to the methods and apparatus in use by millwrights in the past, it may be well to call attention to some of the methods and apparatus which we did not have at the time I first began working at millwrighting fifty years ago.

At that time there were only three or four short railways in the country, and those amounted to very little as a means for doing business. Steamboats were the "ne plus ultra" of human achievement at that time. Just imagine this country to-day without its railways. At that time there were very few steam engines on land, and those used wood for fuel. I traveled a long distance to see the only one running, in a city of thirty thousand inhabitants in the State of New York. The telegraph was unknown. The planing machine for planing and matching boards, known as the Woodworth planer, was not in general use; and the Daniels planer, for planing timber straight and true, was only found in a few establishments, and the same may be said of the iron planer now used in every machine shop. The band saw was unknown, and the circular saw for sawing lumber was in but a few mills in the country. Many of the tools in the millwright's tool chest were of the antiquated English style. No ready-made shafting or pulleys were kept on hand. Ready-made belts, crudely made, were just coming into use, and many belts were home-made. Rubber belting and other rubber goods were unknown.

No ready-made bolts or lag screws were to be had. The blacksmith made all bolts, and cut the threads by hand, making them cost fifteen to eighteen cents per pound, and of inferior iron and workmanship; so that a good millwright, who then worked for $1.25 to $1.50 per day, would work a whole day to make some wooden device to save six or eight pounds of bolts.

Nearly all machinery was driven by water power, and all good mills used the overshot or breast wheels, except sawmills having the old style, vertically reciprocating saws, some of which used "reaction" wheels, and very few wheels of 100 horse power were to be found.

The largest and most powerful wheel in the country at that time was an overshot wheel sixty-two feet diameter, at the Burden Iron Works, at Troy, N. Y. At about the time mentioned, the first turbine wheels for heavy work were put in the cotton mills at Lowell, Mass. They were of the Fourneyron type, and gave good results; but the cost of such wheels placed them beyond the reach of most mills in the country for many years, so the old millwright was left to plod along in his old way for some years, building overshot and breast wheels, with wood shafts, having cast iron "gudgeons" for bearings, which wheels most of the mill owners believed could not be equaled for efficiency, to say nothing of being superseded by the "new fangled" iron wheels, as they were called.

In those days, if a water power was to be developed, the millwright was the man who engineered the building of the dam, races, flumes, and wheel pits; determined the size of waterwheels required, designed the buildings, located the machinery, and arranged the shafting and gearing, also determined the sizes of the gears, shafts, pulleys, and belts to transmit the power to the several machines.

Large pulleys of six feet diameter or more were little used, and were mostly made of wood by the millwright, and large belts such as now universally used were not made, cast iron gears and frequently cast iron shafting being used for heavy transmissions of power. Mortise gears for wood teeth were occasionally found, but could be made by only a few shops in the country, and the rough iron pinions which worked with the mortise gears were fitted with cogs of no particular form, some of which were short-lived noisy affairs, while others would run well a long time. Many mortise gears were made by millwrights entirely of wood. I was once the owner of a grist mill, which was fitted to grind feed (from corn in the ear), corn meal, buckwheat flour, and wheat flour, the mill having, in addition to the mill stones, the usual outfit of elevators, "smutter," hulling machine, conveyor, Boults reels, corn cracker, and hoisting rig to take grain from a wagon at the door; and the only belts in the mill were the canvas belts in the elevators and conveyor, to which the cups were attached, and one leather belt to drive the smutter, for cleaning the wheat, and the mill ran many years in that shape before I owned it.

The great amount of experience or practice necessary to qualify a man to be a successful millwright required a large portion of a lifetime, and when we look about us to-day and see how the field of mechanical knowledge has enlarged from a little garden patch to a boundless prairie, and each branch has become a separate department of work more or less scientific in character, and requiring and employing men of the highest ability, we can realize that the progress has been simply enormous.

There is considerable knowledge worth saving from the old millwright practice, which is indispensable to the man doing such work to-day, and I am reminded that few young men are now learning the business, while the demand for practical and reliable millwrights is increasing every day, and I have been puzzled to explain or to understand why our Society of Mechanical Engineers have so completely ignored the subject. While a large part of the motive power which is moving the machinery of the world, and which is now being largely used to generate electricity, is water power, it seems strange that so great part of the time and efforts of every one should be devoted to steam power development and so little to water power, which I think is of equal importance.

RUSTLESS COATINGS FOR IRON AND STEEL.*

PAINTS: OF WHAT COMPOSED, HOW DESTROYED, CLASSIFICATION AS TRUE PIGMENTS AND INERT SUBSTANCES, ADULTERANTS, ETC.

By M. P. WOOD, New York City, Member of the Society.

WHAT is paint? This question can be answered in a broad way by saying: It is any liquid or semi-liquid substance applied to any metallic, wooden, or other surface to protect it from corrosion or decay, or to give color or gloss, or all of these qualities, to it.

A better definition would probably be, that paint is a compound of a pigment and a liquid, usually applied to any surface with a brush, for the purpose of protection, or to secure artistic effects; which liquid, after undergoing certain changes, in part mechanical, or chemical, or both, has the power of holding the pigment to the surface of the coating. It is evident that the latter definition would also include those compounds that are applied to many surfaces either hot or cold as a bath, or by immersion rather than by a brush solely as a matter of convenience or rapidity; and particularly so when metallic members of large size, or with intricate and hidden parts, are to be protected. In the latter case the term coating would probably be the better definition.

The essentials of a good paint, for whatever use intended, are:

First.—That it shall adhere firmly to the surface over which it is spread, and not chip or peel off. It must be non-corrosive to the material it is used to protect, as well as to itself under long periods of atmospheric exposure and chemical changes. It must form a surface hard enough to resist frictional influences, yet elastic enough to conform to all changes of temperature, or with a coefficient of elasticity approximately as near the material it covers as possible. It must be impervious to and unaffected by moisture and atmospheric and other influences to which the structure may be exposed.

Second.—That it shall work properly during its application, a property that depends largely upon the relative amounts of pigment and liquid; the nature of both pigment and liquid also have influences that govern results.

Third.—That it shall dry with sufficient rapidity. This function depends mostly upon the vehicle or liquid used with the pigment, though the pigment has in many cases an influence, as will be seen further on.

Fourth.—That it shall have proper durability, which is a function both of the pigment and liquid. And as the question of cost is in many cases the governing factor in the selection of a paint, the question of durability may be regarded as the most important one of the list; though it can be imagined that a paint can be durable per se, and not be protective in the strict sense of the word, as can be illustrated in the case of a good paint applied to the surface of a sheet of iron coated with rust; the liquid element in the paint will not absorb or neutralize the corrosion which it covers, but will dry regardless of it, and permit the destruction of the metal to progress beneath its coat.

Fifth.—Covering power, by which is meant the power of a pigment to so cover the surface to which it may be applied that its protection from decay is not only assured, but that the minimum amount of paint shall effect this purpose.

Master painters and color manufacturers vary greatly in their definitions of the covering power of paints, and are inclined to classify it into "coach painting and house painting," with a distinction whether it is internal and decorative, or external, both protective and decorative.

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The covering power is also used to express the power of a pigment to protect the oil from decay, in which case a large amount of pigment and a small amount of oil are used; this description of paint drying more or less "flat," the pigment being exposed to the weather and held in place by the thin film of oil. It is thought by many master painters that this is the most durable and best paint for general use. On the contrary, paints that dry with a gloss have a large amount of oil and a small amount of pigment, in which case the oil covers and protects the pigment.

It may be used to express the amount of color upon the surface; as, generally, if a surface has plenty of color upon it, the covering power is said to be good. To illustrate this definition: If an iron oxide paint is proportioned so that the ratio between the pigment and the oil is by weight fifty per cent. of pigment and fifty per cent. of oil when the paint is ready for spreading, and the pigment consists of thirty to forty per cent. of iron oxide, the covering power will be said to be good; but if the same proportions of fifty per cent. ratio between the pigment and the oil be had, in which the iron oxide is only five per cent. of the pigment, the covering power would be called poor; and so it would be in the case where ten per cent. of pigment and ninety per cent. of oil were used. If in the two latter cases the oil contained large or liberal amounts of volatile diluents, the appearance of the surface would indicate a deficiency in the covering power of the paint.

The covering power is also commonly expressed in the amount of surface that a given weight of paint will cover. A good iron oxide paint will cover nearly twice as much surface as white lead or red lead. The specific gravity of the paint also is to be considered in the definition of this power. The lightest paints have the most covering power. White lead is about 6·4 times as heavy as water; iron oxide five times; yellow ocher three and one-half to four times, etc. With this variation it is manifestly almost an impossibility to get the same number of particles of the same size out of the same weight of different materials.

The refracting power of light has much to do with an understanding of this covering power of paint. The greater the refracting power of the pigment is over that of the oil, the better will be the covering power. The index of refraction of air is one degree; water, 1·31; linseed oil, 1·48; glass, 1·50 to 1·55; silica, 1·55; feldspar, 1·54; whiting, 1·65; chrome yellow, 3·00; vermilion, 3·20, etc. There is no exception to the rule that the finer the state of division to which any pigment is reduced, the better will be its covering power. Sulphate of lime, barytes, feldspar, silica, talc, whiting, etc., are all of low refractive power, and of themselves, independent of this refractive quality, do not constitute good pigments; though when mixed with the metallic pigments and ground together in the oil the result is a pigment of good covering power, almost as good as the better one of the combination. For instance, eighty per cent. of sulphate of lime and twenty per cent. of zinc white form a pigment almost as good as all zinc white, and ten per cent. of white lead and ninety per cent. of talc, carefully ground, give a very satisfactory result so far as relates to the covering power; but all of the above and other kindred compositions, while improving the covering power, are possibly to be classed as adulterants, the use of which may be objectionable so far as durability and protective power are concerned, when the question of cost is not considered in connection therewith.

As stated before, the finer the pigment is subdivided or ground, whether as a paste that is afterward thinned with oil or volatiles to a consistency to spread with a brush, or is ground in the oil direct (a process that all pigments will not endure without injury to their color, the scarlet lead chromate, for instance) to the proper consistency to spread, the better will be its covering power.

An ounce of lampblack, because of the minuteness of its particles, will cover more surface in an effectively protective manner than any known pigment, and one part lampblack and nine parts sulphate of lime by weight gives most excellent results in covering power. Prussian blue, the scarlets, lakes, and others of what can be called "the fugitive colors," on account of their tendency to fade out, possess the light-dispersing power which deceives the eye as to their covering faculty, when in reality for actual covering as protective substances they are absolutely worthless. These colors should be denominated stains rather than paints; and generally the only measure of protection from decay or corrosion that accompanies their use is solely from the oil or liquid with which the color is mixed.

The designing of a paint, for whatever purpose to be used, necessarily includes the qualities already mentioned, viz., adhesion and elasticity, working qualities, drying qualities, durability, covering power. The other quality, the cost, cannot be ignored, and will be duly considered later, as well as what pigments to use for the intended purpose. All pigments do not contain all of the above qualities. The question naturally arises: Is it necessary for a pigment to be pure and unmixed with inert substances, or can a certain amount of these be mixed with the pigment without detriment to it?

Experiments of long continuation lead to the conclusion that the oxides of iron, lead, manganese and other strong pigments can be mixed with large amounts of these inert substances without detriment, and generally to the manifest improvement of the paint as a protective agent on many structures, notably wooden or composite ones. A single illustration will suffice to make this apparent. Oxide of iron is one of the strongest of pigments in covering power. If one ounce of this pigment be spread in two coats over a given surface, say two square feet, so that the surface be completely hidden, and the job be declared a satisfactory one so far as covering power is concerned, and in the second case an ounce of the same oxide of iron be mixed with three ounces of barytes, kaolin, gypsum, etc., or any one of them, and this paint be spread over two square feet of surface as before, it is obvious that the amount of color per unit of surface will be the same in both cases; but in one case there is four times as much pigment as in the other, and in the second case three-fourths of the paint would be inert material. For railway cars and wooden structures the durability of these paints would be in favor of the second case, as well as the cost of the paint. The pigment in this case is the life of the paint, and protects the oil from the decay incident to oxidation from the atmospheric exposure.

Oxide of iron is practically unchanged after centuries of exposure. It induces and promotes oxidation in all organic substances with which it is brought into contact, as well as in nearly all metallic bodies. In an oxide of iron paint it is the oil that decomposes (being the organic matter), the decomposition due to the exposure of the elements being aided by the oxidizing power of the oxide of iron pigment mixed with the oil. This statement holds true only where there has been no chemical change or combination between the pigment and the liquid.

Whiting, sulphate of lime, barytes, kaolin, silica, feldspar and talc are the principal inert substances used in pigments. Whiting, gypsum and barytes are the best of the list; the others, grinding greasy, or hard to grind, or of a nature readily decomposed by water, are objectionable.

Barytes, from its great weight, is objectionable only when bought by the pound in a dry state, or as a paste or prepared paint in which as an adulterant it takes the place of pure material. The sulphate of lime is no doubt the best of the inert substances to mix with any pigment, all things considered. It should be thoroughly hydrated. As high as 45 per cent. by weight of this substance can be mixed with 50 per cent. of sesquioxide of iron for a pigment.

As most of the oxide of iron paints are made by ignition of copperas, and a small amount of sulphuric acid is sometimes left in the oxide that the heat has failed to drive off, from 2 to 5 per cent. of carbonate of lime is added to neutralize the free acid, changing it to sulphate of lime. In this case of proportions, the pigment really consists of 50 per cent. of oxide of iron and 50 per cent. of inert material, all by weight. Any oxide of iron paint that contains hydrated oxide or free SO_3 will deteriorate rapidly by oxidizing the liquids, while any free SO_3 will retard the drying of the paint.

A good paint prepared for spreading in ordinary temperatures upon wooden or composite structures has the ratio of about one-third pigment and two-thirds oil or liquid. The practice upon one of the leading railways of the United States, where the materials purchased for paints amount to over $300,000 yearly, is to allow 75 per cent. of pigment and 25 per cent. of oil for the paints applied to cars and wooden structures.

Experiments determine that the most durable paints are those that contain a large amount of pigment per unit of surface; and that pigment is the best that is strong enough of itself, or with a proper proportion of inert material, to allow liquid enough to be added to it to flow and work well with the brush when applied.

The destruction of paint may be from eight causes: First, mechanical injury; second, the action of deleterious gases; third, chemical action between the pigment and the vehicle or liquid; fourth, chemical action between the body covered and the paint, either the pigment or the liquid; fifth, the action of light; sixth, peeling; seventh, destruction by cleaning; eighth, water.

Many master painters and manufacturers claim that the destruction caused by cleaning and the action of water are the worst of the above causes. This is true so far as paint applied to wooden structures is concerned, and has no relation to the causes that effect the destruction of paint applied to iron or steel structures.

As most of the above destructive agents are common to all structures (wooden, metallic or composite) that depend in a greater or less degree for their preservation from decay or corrosion upon paint (under which name I class all paint oils, varnishes, japans, surfacers and mixed paints), it may not be amiss to briefly discuss each of these causes in detail before citing the destructive agencies that relate solely to the corrosion of metallic structures, the prevention of which will require the consideration of other preservative methods than paints, or that may be used in connection with paint to secure the best protective results.

First.—Mechanical injury, in a certain sense, as applied to wooden structures, is not a serious cause of deterioration of paint. Near the seashore the sand has the effect of a sand blast to rapidly cut away the paint, and in this case the more elastic the paint is, the less will be the mechanical injury. This sand blast action is quite as effective in the case of iron structures, and as generally they are of a more important character than the wooden cottages or residences, and minor buildings on the sea coast, its action must be guarded against. If the paint coating is of a soft, spongy nature, it will resist the sand blast, but will absorb moisture from the air, and hasten either the oxidation of the paint or the metallic surface which it covers. Verily, as between the devil (the sand blast) and the sea air, it is hard for the engineer to choose into whose hands he would better fall.

A further injury to metallic structures can be classed under the head of mechanical, viz.: That arising from the expansion and contraction of the various parts from the atmospheric changes that are constantly going on, changes ranging from 40° F. to 150° F. not being unusual. Now, it may be considered an impossibility to proportion a paint compound so that its coefficient of elasticity will be the same at all temperatures as that of the metal it covers. It may be possible to do this at some temperature at or between 60° and 90° F., or even between + 40° F. and 90° F.; but that any paint in the class of commercial colors will do this at all temperatures is the tale of the salesmen, not of the engineer.

It may be argued that these changes, coming from the external surfaces of the paint and being transmitted through its coating, it will be the first to adjust itself to the new or varying relation between the metal and the paint, and so will work to the advantage of the paint in making the change, this being in ordinary cases a gradual one. If the paint is of an elastic, close clinging material, and not a hard, vitreous one, the claim will hold good.

The compounds that most closely partake of this nature will be spoken of hereafter. An addition to this problem will be had when the strains due to the action of wind, the passage of railway trains, and those due to changes of a sudden and vibratory character, together with the action of snow, hail, and water driven at high velocities, are added to the temperature changes. Over these combinations a little coat of paint is required to stand perpetual sentinel. These latter mentioned strains necessarily come to the metal first, and whatever changes in section of the bars or elongation of them by the strain occur, the paint must accompany them. As these strains are generally of a vibratory or percussive character, it can easily be seen why they should be classed in the list of mechanical injuries. In fact, they are a succession of blows that the structure must withstand, absorb and extinguish within itself or its connections; the structure then returning to its normal condition, the paint or other protective covering must accompany it, instead of loitering by the way and being grounded or "left" in the chain of operations.

Second.—The action of deleterious gases is very familiar to those who have studied paints and protective compounds. Sulphureted hydrogen is one of the most common and active of these gases, and is formed in excessive amounts wherever coal is distilled, as for illuminating gas. Sulphurous acid fumes also, being disengaged in the combustion of coal in the many arts, transportation and manufacturing processes of the day; gases engendered in workshops, being of a compound character carrying ammonia, carbonic acid, nitric acid and other fumes, are active agents of corrosion to metallic bodies, as well as the paint compounds that cover them. White lead is the pigment most affected by these fumes, the action of the sulphur changing the carbonate of lead to a sulphide of lead; rains or any condensed moisture then washing it away and leaving the surface coated with it exposed to the elements of decay.

Third.—Chemical action between the pigment and the vehicle or liquid. This is an exceedingly important field of inquiry, and largely an unknown one. The siccative and other oils that are in common use for paints are all capable of saponification. It is well known that soda and potash are not the only substances which combine with fats to produce soap, and that almost any of the bases can be combined with the fat acid of nearly all oils to make soap; hence we have iron soap, lead soap, zinc soap, manganese soap, etc.

Many pigments are simply oxides or hydrates, in the same way that soda and potash are, and it is strongly suspected that they combine with the oil to form soaps, in which case it will be evident that, after the paint has been left on the surface for a number of years, instead of a pigment held to the surface by the liquid and which has undergone certain changes called "drying," it is in reality a new chemical body consisting of the constituents of the liquid combined with the pigment, or, in other words, it may be a soap.

Fourth.—Chemical action between the body covered and the paint, either the pigment or the vehicle. The chemical changes that may or do take place between the pigment and the liquid, as set forth in Article III, can be supplemented here to embrace those paints that contain pigments, one or more of which give up oxygen or break down in the presence of organic matter, the oil or liquid of the paint. Hydrated oxide of iron (iron rust) oxidizes organic matter (the oil) and gradually destroys it. Oxide of iron paints of all kinds gradually grow darker with age from the oxidation of the oil, this oxidation progressing until either the paint cracks and falls off as a scale on any mechanical disturbance, or is washed away in the process of cleaning or by the action of storms. The chromate of lead, bichromate of potash, the chlorates, manganese dioxide, red lead, and a number of other pigments also possess this oxidizing power to a great degree, but are also possessed of another chemical property that, when these substances are used as pigments and applied to iron and steel surfaces, renders them almost proof against the effects of corrosion.

This property is the power to form on iron and steel surfaces a thin coating of black or magnetic oxide, that so effectually protects the metallic surfaces from corrosion that after the removal of the paint the metal still resists atmospheric effects for a long time, as well as the stronger effect of immersion in sea water or acidulated waters, sulphurous and other vapors. This action is very obscure and not thoroughly understood; but the fact remains, and extended experiments in this field only demonstrate its presence and usefulness. Practically it is the same coating that the Bower Barff, Bertrand, Maritens, Gesner, and other kindred processes develop when iron and steel objects are placed in a closed vessel or muffle and exposed for a few hours to a low red heat (1,000° to 1,200° F.) with the action of superheated steam, naphtha, or other hydrocarbon vapors, forming, at the expense of the metal itself, an oxide of varying thickness, according to the period of exposure, that is non-corrosive, and, what is further an anomaly, a coating that is electro-negative to the iron surface it covers, but is also electro-negative or passive to the paint that covers it when the pigments composing this paint are composed of one or other of the above mentioned oxidizing materials other than the oxides of iron, zinc, tin, or lead. This magnetic oxide power in paint as applied to wooden structures is still less understood than its action upon metallic surfaces, and may not be of the same importance, as the artistic effect of a fresh coat of paint upon a weather beaten wooden or brick structure may appeal more forcibly to the eye than any other factor to cause a fresh application of the paint covering.

Fifth.—The action of light. The action of light as a bleaching element is well known in almost all fields of human industry; but the chemical changes that occur between the pigment and the liquid are not well understood, this action being furthermore complicated by the different temperatures to which the coated surface may be exposed, and aided by the effects of sea air or fumes from various manufactories. We know that certain pigments fade upon exposure, whether applied to metallic or other structures. The pigments that contain organic coloring matter from coal tars, dye woods, etc., fade more rapidly than those which have a metallic base. The fact remains, however, but it has never been established, that the bleaching of the paint in all cases detracts from its durability.

Sixth.—Peeling. Paints vary greatly in their power to adhere to either metallic, wooden, or other surfaces; notably zinc white, which peels under almost any condition or from any surface to which it may be applied.

There is no other pigment that possesses this property in so marked a degree, and it is difficult to assign any reason why it should peel so badly. A possible theory is that the zinc white combines with the oil used in the paint and forms one of the compounds known as metallic soap, this particular one being zinc soap, a hard, brittle, non-adhesive substance, easily removed by mechanical injury, water, and in the process of cleaning, etc. Galvanized iron possesses the property of causing almost any paint applied to its surface to peel; in fact, it is one of the worst substances to cover with a pigment in a satisfactory manner. Experiments were made by a leading railway company in the United States, in which a number of the best pigments in use by that company for all descriptions of railway work were tried upon galvanized iron car roofs and other galvanized work, cornices, etc., showed at the end of three years that but one of the list was in any manner satisfactory, and this one was a patented compound whose component parts have not been ascertained. Ordinary trade colors are of the most unreliable nature when applied to galvanized iron exposed to the trying conditions of railway service. Various reasons have been given for this peculiar action of paint upon galvanized iron. One of the most plausible is that the use of sal-ammoniac in the process of galvanizing causes the formation of a thin film of the basic chloride of zinc on the surface of the metal being galvanized, which material, being of a hygroscopic nature, acts as a repellent to prevent the close adherence of the paint to the metal, and the pigment dries as skin over it. Sheet zinc that has not been through the galvanizing tank does not hold some kinds of paint. Sheet lead also is difficult to cover, and paints that take tin and lead will not always adhere to zinc. As a general rule, the strong oxide paints take these metals better than talc, ocher, and the earthy pigments. No positive general statement can be given, and the problem of the adaptability of paint to a metal to prevent peeling still needs study. A paint for the prevention of corrosion in metals should embrace those qualities that will cover both of the above requirements, and the solution to that problem I hope to be able to give.

Another fruitful cause of the peeling of paint is when the several coats are successively applied before the foundation or preceding coat has thoroughly dried, the result being that the liquid in the outer or last applied coats softens the pigment in those previously applied. The resulting mass, containing a notable amount of the more volatile elements of the liquid, beginning to dry from the outside surface, forms a thin but hard or vitreous surface that retards the further evaporation of the volatiles and prevents the access of oxygen from the air, which is necessary in the process of drying. If the surface thus covered has been painted while at a low temperature or during a damp or foggy atmospheric condition, and soon after there is a marked rise in the temperature or a fall in the hygroscopic condition of the atmosphere, then the paint is liable to peel at once, or soon after the change. This effect is hastened in the case where the coating is a heavy one, or one hard to spread by reason of the earthy or inert substances in the pigment, or if benzine has been used as a drier. As a general rule, the more substances that enter into a coat of paint, either as pure pigments, inert substances, or in the composition of the liquid, the more liable it is to peel. A small amount of fish or animal or non-drying vegetable oils, though oxidized by the addition of metallic salts and used in connection with linseed or other siccative oils, also hastens and provides for the certainty of the peeling.

A pigment composed of a number of substances, the different materials of which by themselves would form the basis of a good paint, when combined together with the liquid necessarily must undergo a different chemical action than the several members of the pigment would have done had they been used alone. This chemical action is furthermore complicated by the combinations going on in the liquid, which, formed of a number of different elements that act and react upon one another, and mixed with the heterogeneous pigment, develops a series of chemical actions in the mass, the weaker element of which, either the mineral or the organic, is the first to break down or change, the decay of which hastens the decomposition of the others and releases the bond between the paint and the surface over which it is spread, and the peeling process is effected.

That these chemical changes exist in the above stated case cannot be denied, but have not been well accounted for. The fact remains, however, that certain paints peel, and though analysis of the peeled portion may reveal nothing to indicate the reason for the peeling, it is seldom possible to get a sample of the original paint as applied, to compare its constituents with the peeled sample, and the cause is relegated to the hidden drawer of the paint shop, near which some scapegoat can be found to bear the burden of failure.

Seventh.—Destruction by Cleaning.—This cause of the deterioration and destruction of paint relates more particularly to wooden structures, railway cars, and kindred objects, than to those of a metallic character. It may be sufficient to say we do not wash down an iron bridge, roof truss, or steamship, with a view to its presenting a clean face for the not too frequent inspection. Almost all the binding materials of dried paints and varnishes are more or less acted upon by caustic and carbonated alkalies, and but little of the soap in the market is free from these substances. The detergents sold for cleaning are all mixtures of salsoda with lime, pumice, and other inert materials, and the more effective they are for removing dirt, the better they are for the destruction of the paint. If, in the economy of domestic household matters, two removals are equal to one fire, then it may be cited with equal force that two good scrubbings with any washing compound and most of the soaps of commerce, applied with a stiff brush and by a willing servant, will be equal to the next painter's bill to restore matters to their pristine state. Aside from the element of cost, it is no doubt the better practice, so far as the ultimate preservation of any metallic structure is concerned, that it should be washed clean with some of the detergent compounds of the day to remove the dirt, then sponged with a liberal amount of clean water, then be allowed to dry thoroughly before the new paint is applied; but I must confess, as an engineer, that the above method of painting is a rare occurrence, and that the rule is for the paint to be put on regardless of cleaning the old coat, and like charity, trust it to cover the sins beneath.

Eighth.—Water.—The destructive action of water upon paint applied to any structure, wooden, metallic, brick, or composite, upon their internal as well as their external surfaces, is very strong, and will rank next in destructive qualities to the detergent soap and scrubbing brush. Inside painting lasts longer than outside, principally because it is less exposed to the action of water. Direct experiments show that dried linseed and other siccative oils, when applied to a surface alone without pigment, are not resistent or water repellent. When the oil is well dried, the application of water always causes the oil to assume a shriveled appearance, showing that it has absorbed moisture and expanded, and disintegration has commenced. If the exposure be long continued, the whole coating of dried oil will slump away from the surface over which it is spread. Rain water, from the sensible amount of ammonia that it carries, increases this destructive action on the dried oil; and the slow wasting away of good paints containing pigments best known to resist aging influences, and that have been hardened by time, can be attributed to this action.

The ordinary test by master painters of the ability of an oil or paint to resist moisture is to coat a surface, usually of glass, and, when well dried, to immerse it in water for a few hours, and note the changes in color and integrity of the paint or sample.

Dr. Dudley's experiments for the Pennsylvania Railroad, on the action of water upon paints, are interesting from the care which was exercised in making them and recording the results. Several samples of a paint designed for use upon cars and wooden structures were made with raw linseed oil and a very small amount of japan; the same liquid being used for all the samples with varying amounts of pigment, all the proportions being by weight. Two coats of these paints were spread upon glass, and allowed to harden for two to three weeks. These samples were then placed side by side, and a small portion of the surface of each covered with a globule of water. This globule was covered to prevent evaporation, and then allowed to stand for twelve to fourteen hours.

No 1	was the linseed oil and japan alone.				
" 2	"	same liquid	90 parts,	pigment	10 parts.
" 3	"	"	80	"	20 "
" 4	"	"	70	"	30 "
" 5	"	"	60	"	40 "
" 6	"	"	50	"	50 "
" 7	"	"	40	"	60 "

When the proportions are higher than liquid 40 parts and 60 of pigment, the paint will not spread well with a brush if the liquid is linseed oil and the pigment has the specific gravity of ordinary oxide of iron paints.

At the end of the period named, the behavior of the samples was as follows: No. 1 coating was found to have cleaved off from the glass and had become shriveled wherever the water had touched it. Apparently the dried linseed oil had soaked up water, much as a sponge acts as an absorbent. On allowing the water to evaporate, the coating dried down again, but not uniformly, and was apparently weakened in texture.

No. 2 showed the same characteristics.

No. 3 showed the same, but in a less degree.

No. 4 did not cleave off from the glass, but showed where the water had stood.

No. 5 showed a spot in the same way, but in a less degree than No. 4.

Nos 6 and 7 showed but very little action.

It can be noted here that linseed oil dried for some two months absorbs less water than freshly dried oil, while very old dried oil has lost this absorbent quality and has become almost water repellent. To successfully design a paint that will resist all of the previously named destructive agencies, and at the same time resist the destructive action of water (or moisture), is a difficult matter. The field is an enormous one to cover, and but little positive knowledge has yet been obtained, though the investigators and experiments have been legion, and the literature on the subject embraces volumes. Time is an essential factor in the test of the qualities of a paint, and if the experimenter is required to wait five or ten years to determine the merits of any paint, or what effect a slight modification of the proportions has upon any one or more of the eight destructive agencies heretofore stated, a life could be spent and possibly not a conclusion drawn.

Experiments are numerous in the field of designing a waterproof coating to be applied over the pigment that has been found to possess the most preservative qualities, independent of the water-repellent features, but it can hardly be said that the goal has been reached at the present hour. How effectually a thin coating of the proper material can protect the surface of a paint that it covers, can be seen in the lettering of old signboards, which is perhaps an example of the most durable paint of which we have any record. Reference has been made to this subject in a previous paper, No. 598, vol. xv, p. 1021, and need not be repeated here. This protective effect is explained by the well-known fact that lampblack is one of the best water repellents known; that it is practically indestructible, and being per se of an oily or greasy nature, when mixed with a pure oil (linseed in these cases), and being in a measure elastic, it has effectually preserved the surfaces, and not allowed the water to reach the underlying coats of white lead.

If the question of color did not to a greater or less degree govern the kind of paint to apply to any important structure, we could soon arrive at a solution of the question, how to preserve it. It is told of the fireman, when the question came up as to what color he wanted the fire engine to be painted, replied, "I do not care, so she is red." And so with our iron structure: we can paint it with the best paint for preserving it and which will be pleasing to the eye, and then give it a coating of lampblack to preserve the covering, attaching thereto the familiar notice, "For particulars inquire within."

Having set forth the general character of what a paint should be for the purpose of protecting structures from decay or corrosion, and having indicated the most effective causes that provoke or promote the destruction of the object and its protector, it may not be amiss to speak more definitely upon those materials that enter into paint compounds that yield the best results in general practice; these results being based upon the experience thus far at hand as recorded or accepted data, and not the hypothesis of some person or persons whose single or joint lives may be too short a period, as compared with the life of the structure they are striving to protect from decay, to realize the meritorious features of their experiment.

Engineers as a class are not much less subject to whims than their less prominent brothers in craft, the master painters, color manufacturers, and others, whose trade secrets are too often of too small moment to produce the important results that are claimed for them. Many an important structure has failed from the inadequate means employed to preserve it. Had the original methods employed to protect it been made a matter of record in full detail as to the composition of the protective coating, as well as to how the structure was prepared to receive it, we should be further on the road of engineering experience, and be far better prepared to tell what to do in the practice of to-day in order to secure an abiding result in preservative methods.

The several governments of the civilized world, by the magnitude of their expenditures in the mechanical arts, in the form of the ships, buildings, lighthouses, docks, and the scores of other metallic structures, either manufactured by themselves or bought for their use to the amount of millions of dollars or pounds sterling annually, from the very nature of things ought to be the repository of the best methods of preventing their decay; and the recorded data should be so full of detail as to the actual results obtained from certain experiments, the favorable nature of which has determined the practice of the several construction and repair departments connected with the government service, that there should be little question of what not to do, even if the more momentous one of what to do is undeveloped and uncertain. In most of the navy yards, however, the few rules, or the information what to do in certain cases, is as zealously guarded as a trade secret, obtained at the expense of the public for the apparent benefit of the knowledge-box of somebody connected with that particular navy yard, as any private manufacturer ever practiced to keep his trade at home or intact from others' meddling.

The substances in use for coatings or paints for the preservation of all structures, wooden and composite, as well as metallic, from decay or corrosion, are:

First.—Mineral or natural asphalt, artificial asphalt and coal tar compounds, either applied alone or in combination with each other, and with more or less certain inert substances in use as pigments, viz., barytes, whiting, gypsum, kaolin, silica, talc, feldspar and sundry ochers and substances with metallic bases, used to give body, cheapen the cost, change the color or to correct some suspected or known deleterious constituent, such as ammonia, sulphuric acid and other compounds that accident or design has placed in the vehicle or liquid, or that may be in the pigment naturally, or have been developed by the process of manufacture. The characteristics of these inert substances when used as pigments will be referred to hereafter.

Second.—Iron oxide paints.

Third.—Zinc and lead oxides and carbonates; sublimed lead; manganese dioxide ore.

Fourth.—Carbon paints; graphite, lampblack.

These will be considered in turn, and the principal characteristics given so far as experience has determined their merits as protective compounds or recorded and trustworthy data are at hand to draw conclusions from.

(To be continued.)

THE PRODUCTION OF DIASTASE AND OF AN ALCOHOLIC FERMENT FROM FUNGI.

THIS discovery is due to a Japanese chemist named Jokichi Takamine, who, while studying with Professor Mills, F.R.S., at Glasgow University, conceived the idea of improving the methods of brewing and distilling—that is to say, he satisfied himself that better converting and fermenting agents were obtainable, and that the tedious, costly, and not overhealthy process of malting was a clumsy and primitive mode of obtaining a converting agent in the form of the small production of diastase developed at so much sacrifice to the grain treated. On returning to Japan, Mr. Takamine, jointly with Professor Atkinson, of Tokyo University, who published occasional contributions on the subject, undertook a long and exhaustive series of studies and experiments on many kinds of microscopic fungus or mould growth, his object being to find a class of plant containing the two qualities of converting starch in cereals into sugars and the sugars so obtained into alcoholic spirits. The various ferments and processes of the East, as well as of Europe, were one by one investigated only to be discarded by him; the ergots of rye and other plants whose qualities and powers are well known were not neglected; many kinds of bacteria were studied, when eventually this chemist discovered what he required in the fungus of the species Eurotium oryzæ, a mycelial of the Aspergillus family whose nature and characteristics were almost unknown. The qualities required and found in this fungus were threefold—that is, the plant having the two qualities he was seeking had to possess another quality, that of being capable of withstanding a high artificial cultivation or development of the two qualities. The best and most practical medium used for growing the seed of this microscopic fungus is common hydrolized wheat bran, on the flakes of which the plant grows with great rapidity, and while growing it, to reproduce its own seed, is fertilized with certain chemical salts, and when matured, a process of about five days' duration, he calls it "Taka Moyashi." When grown for commercial purposes it is not fertilized, neither is it allowed to ripen in the same high-class cultivation in this form, the commercial product being known as "Taka Koji."

On examining Taka Koji with a microscope the bran flakes show, after being thirty-six to forty hours in a moist temperature of 80° F., that the roots which spread all over the surface of the bran are literally

covered with minute crystals of pure diastase. At the top of the mycelial a small head is formed in which the seeds and pollen are present. While the diastase at the roots is the ferment or agent which converts starch into sugars, the unripe seeds permeated with the pollen, and which may be designated in this condition spores, give rise to the ferment or agent which converts the sugars into alcohol and which now takes the place of yeast, as the diastase replaces malt. Strange to say, when both characteristics of the fungus are at their best in this inferior cultivation as described, their properties are at their highest stage of commercial utility; but should the higher temperature and fertilization be resorted to, it is found that the diastase is entirely absorbed from the roots by the seed in the head of the mycelial, which it serves to nourish and ripen, and when the two agents become one, capable of reproducing their genera, it is found to be of little use for either purpose—for converting or fermenting. Mr. Takamine obtains his diastase in an almost pure and concentrated form by the use of percolators, washing the diastase from the bran with water, in which it is soluble, but not so in alcohol, in which it is precipitated. When dried it is of a pure crystalline nature, capable of preservation for any length of time.

The purified diastasic product consists of small tenacious, gummy particles of a light brown color, and somewhat of the appearance of finely broken shellac; it is almost devoid of taste, but it communicates a peculiar sensation on the tongue, indicative of active digestive properties. An analysis which we made gave the following results:

	Per cent.
Moisture	15·46
Albuminoids (N = 3·65)	22·80
Mineral matters, consisting chiefly of soluble phosphate	16·22
Non-nitrogenized matter, probably carbohydrate	45·52

On trying a weighed portion with a standard starch solution it was found that over one hundred times of its weight of starch was completely converted in thirty minutes at blood heat. Doubtless at higher temperatures it would convert even a much larger quantity, it being stated that under favorable conditions it will digest as much as a thousand times its weight of starch. Hitherto the digestive properties of diastase have been appropriated chiefly by using active extracts of malt, which of course contain a large excess of malt sugar, which in certain cases it is desirable to exclude. The use of the "Takamine diastase" therefore offers obvious advantages on this head. It can be employed, for example, for the malting of milk preparatory to drying, while it can be introduced almost imperceptibly to the taste into beer and other beverages without adding objectionably to the sugary constituents. It can also be compressed into tablets and in that form be obviously useful for a variety of medical and dietetic purposes. The expense of obtaining diastase by the new process is so smal that it will be cheaply available for all purposes, including that of bread making. It is this product of the new discovery, but in a less concentrated and in a less expensive form, which is expected to take the place of malt to a great extent in breweries and distilleries, while the ferment is calculated to replace the present yeasts of commerce in consequence of its greater power, quicker action, and superior keeping qualities.

As already stated, Taka Koji possesses two distinct properties—namely, diastatic property, or property of converting starch into sugar, and fermenting property. It is exceedingly important from an economical standpoint to separate these two properties, as well from the Taka Koji as from each other—a separation that has never before been successfully accomplished on an economical scale—so that when a conversion is desired the ferment property need not be wasted, and when fermentation is desired only the ferment property of the Taka Koji may be employed without waste of the diastatic property. The ferment portion may be directly separated from the dried Taka Koji, in the form of a fine powder, by sifting the Taka Koji. This powder comprises the bloom of the fungus and possesses fermenting properties in a remarkable degree. The residue left after sifting contains the diastatic property, and may be used as a diastatic agent. These two properties may be extracted together from the Taka Koji by soaking or steeping the same in water, thoroughly stirring and then pressing the mass, the diastatic property dissolving in the water, and the ferment part, insoluble in water, becoming detached by attrition and remaining suspended in the liquid. The soaking or steeping, separating and pressing operations may be repeated as often as may be desired, in order to effect a thorough separation. The ferment may be separated from this solution by decantation or filtration. It is in the form of a fine dry powder, composed of young, immature spores of the mycelial fungus, the color varying with the different fungi employed. It consists of microscopical spherical cells possessing the property of being transformed into alcoholic ferment cells when submerged in sugar solution under suitable conditions. Fermentation with this "Taka Moto," as it is called, proceeds with remarkable regularity and briskness, the liquid having all the appearance of a weak acidulated solution of sodium bicarbonate, so brisk is the effervescence. On microscopical examination the deposit was seen to consist of budding cells perfectly uniform and regular in shape and like the spores of mucor or some allied fungus which have pullulated instead of producing a mycelium. Mr. Takamine uses the microscopic fungus Eurotium oryzæ with the best results. But other mould fungi belonging to the genus Aspergillus and to the genera Mucor and Penicillium may also be employed. The Moto may be dried and used for all the purposes for which common yeast is at present used. It is claimed that the aspergillus yeast for breadmaking will work in half the time required by yeast and will produce sweeter and more wholesome bread. It is, besides, less liable to become sour, as the Moto itself will keep for almost any length of time in ordinary climates and temperatures. It is further stated that the Moto has the power of mastering all injurious and parasitical ferments it may encounter, and of giving off its ferment cells of a perfectly regular and pure kind.—The Lancet (London).

DETECTION OF BLOOD SPOTS IN PRESENCE OF RUST.

By Herren MECKE and WIMMER.

THE authors recommend the observation of the absorption spectrum of oxyhæmoglobine in the following manner:

Some particles of a spot occurring on iron are placed on a port object, touched with a small drop of water, and heated for a short time to about 30°, replacing the water as it evaporated. If the spot was old and dried up in a thin layer, the chief part of the coloring matter of the blood is oxidized to methæmoglobine. In order to reconvert it into oxyhæmoglobine they add to the solution on the port object a trace of a solution of tartaric acid, ferrous sulphate and excess of ammonia, by means of a glass rod drawn out to a fine point. Along with the drop they lay on the port object a horse hair, and over all a covering glass. By cautiously raising the superimposed corner the drop of liquid is moved to the middle of the covering glass, under which a second horse hair is pushed. The drop now forms a minute column between the port object and the covering glass, the depth of which needs to be merely 1 mm. in order to obtain an observation of the absorption spectrum. In this manner we may operate with 0·5 cubic millimeter, or only 0·0005 grm. of liquid. If no micro-spectrum apparatus is available, the edges of the covering glass are fixed to the port object with melted wax or paraffin, the eye piece and the illuminating arrangement are removed and the microscope is placed in a horizontal position. The spectroscope is set in front of the microscope in such a manner that the tube of the latter lies in a straight line with the slit tube of the former, the object is illuminated in a suitable manner, and the absorption spectrum is examined.

If the stains are dried upon cloth, it is digested in water, the liquid is evaporated down to a small volume, and a trace of ammonium sulphide is added, which effects the transformation of methæmoglobine more speedlly. This reagent is not applicable in presence of rust, in consequence of the formation of iron sulphide.

Less sharp spectra are obtained after drying up the solution of blood upon some fibers of linen or white silk, laid close together and moistened with glycerin containing ammonium sulphide, covered with a covering glass, and then examined with the micro-spectroscope.

The reduction liquids must in all cases be added cautiously, to prevent the formation of hæmoglobine, the absoption band of which is not so distinct as the absorption bands of oxy hæmoglobine.

If suspicious spots are found on articles of iron, solution in hydrochloric acid often gives a clew to their nature. If a few particles of the substance in question are heated on the port object with hydrochloric acid, the solution contains flocks if blood is present.

The guaiacum test for blood has been recently recommended by Schar. He pronounces a spectroscopic examination, and the production of crystals of hæmin, the most certain methods, and indispensable in the conduct of forensic investigations, but the guaiacum test is still valuable.

It has been urged as an objection that nitrous acid and other oxidizing agents turn the tincture of guaiacum blue; but these substances react without an addition of oil of turpentine, and are thus sufficiently distinguished from blood. The latter (and also hæmatine) transfer oxygen from ozonized blood to guaiacum resin, thus rendering its constituent guaiaconic acid blue. This property (of acting as a transferer of ozone) is shared by blood after it has been heated to about 100°; it is, therefore, not dependent on any ferment present in blood.

For the detection of small quantities of blood Schar mixes the aqueous liquid in question with tincture of guaiacum, and filters. This tincture consists of 1 grm. of the resin in 100 c. c. of absolute alcohol. There remains on the filter finely divided resin along with constituents of blood, if blood was present. The filter is then shaken up in Hanefeld's mixture (consisting of oil of turpentine alcohol and chloroform, 200 parts of each; glacial acetic acid and water, 2 parts of each). The presence of blood is shown by a blue color. A negative result of this test proves the absence of blood, but a positive result is no certain demonstration of its presence.—Zeitschrift fur Analyt. Chem. and Pharm. Zeit., Chem. News.

BREATH FIGURES.

By Dr. J. G. MCPHERSON, F.R.S.E., formerly Mathematical Examiner in the University of St. Andrews.

THERE is something exceedingly fascinating about the curious set of phenomena known as breath figures, and the explanation of their existence. New light has lately been thrown upon their nature; and their study is interesting.

Fifty years ago, Professor Karsten, of Berlin, placed a coin on a piece of clean plain glass, and passed through it a current of electricity. Nothing was seen on the glass when the coin was removed, but when he breathed on the plate the characters of the coin became visible. At the same time Sir W. R. Grove succeeded in producing impressions with simple paper forms. Moser, of Konigsberg, produced figures on polished surfaces by placing on them rough bodies. Riess described a breath track made on glass by a feeble electrical discharge.

But Mr. W. B. Croft has lately been investigating the matter with exemplary care and perseverance; for it requires some practice to manage the electrification properly. This was his most successful plan. Place a glass plate on a table for insulation, and put a coin of any metal on the center of the plate. In many cases the image on the coin does not touch the glass on account of the projecting ring; but these seem to be best suited for the experiment. Arrange a strip of tinfoil from the coin to the edge of the glass; on the coin place a smaller plate of glass, and above that plate place a second coin. Connect the tinfoil and the upper coin with the poles of an electric machine, and turn the handle of the machine for two minutes, so that continuous sparks may pass. On taking up the glass, nothing can be seen on it, even with the help of a magnifying glass. Yet on the glass there is a latent impression; for, by breathing on the side of the glass next the coin, a clear frosted picture of that side of the coin which had faced it will be produced, even to the smallest details. The whole projecting parts of the coin have a black counterpart, and there is a marvelously fine gradation of shade corresponding with the depth of cutting on the coin. If this breath figure be examined under a microscope, the moisture will be seen really deposited over the whole; but the size of the minute water particles increases as the part of the picture is darker in shade. Around the coin's disk is a black ring, a quarter of an inch in breadth. Should the coin used have milled edges, radial lines will pass through this ring.

If these breath figures are carefully protected, there is no apparent limit to their permanence, even for years. Months after they have been set aside, the black ring round the disk gradually changes into several rings, forming beautiful concentric alternations of black and white. If half a dozen coins, lying in contact side by side in the form of a cross, be placed on insulated glass, then over the coins a test glass, with a corresponding cross of coins above it, beautiful breath figures will be produced. In the black spaces between the circles are clear white lines which are common tangents to the circles, when the coins are of the same size. If coins and glass plates be piled up alternately, and the outer coins be connected with the poles of the electric machine, perfect images are formed on both sides of each glass. If several glasses be placed between two coins, only two images will be produced, one on each of the outside glasses. In all cases the glasses must be scrupulously well cleaned with chamois leather.

Heat will produce similar results by the molecular bombardment to which the surface of the cold glass would be exposed by the gases heated by the coin. If a very hot, clean coin be placed on a cold mirror, and be removed after being cooled down, nothing will be seen on the glass. But if the mirror be breathed upon an exact image of the coin becomes visible. If the point of a blowpipe be passed over a clean mirror, with sufficient quickness to prevent the sudden heating from breaking it, nothing is seen after the glas is cold. But if you breathe upon its surface, the track of the flame is clearly marked. While most of the surface looks white in consequence of the light reflected by the deposited moisture, the track of the flame is quite black. But under a microscope this track is discovered to be wet with a thin, even film. If the jet of the blowpipe be tracked over the mirror so as to form figures, the breath on the cold plate will reveal the figures, traced with great distinctness. The hot coin in some way seems to alter the dust particles on the mirror, causing them at certain parts to reflect more light than at others, to be brought out more plainly when the moist breath develops them.

Probably all polished surfaces may be similarly affected. A plate of quartz gives most beautiful images, perfect in details, retaining their freshness longer than those on glass. If a piece of mica be split, and a coin be slightly pressed for half a minute on the new surface, without any current of electricity or application of heat at all, a breath figure of the coin is left behind. If a leaf of paper printed on one side and thoroughly dry be placed between two plates of glass, and left for ten hours either in the daylight or in the darkness (a slight weight being placed over to keep the paper even), nothing is seen; but as soon as you breathe on the glass, a perfect breath impression is made of the print on both pieces of glass. These are generally white, and are most easily produced during keen frost. If paper devices be placed for a few hours under a plate of glass, clear breath figures of the devices will be produced when you breathe on the glass. After an ivory point has been traced in any shape over a glass plate with slight pressure, a black breath figure of the writing is made at once. If plates of glass lie for some hours on a table cover which has on it figures worked in silk, strong white breath figures are impressed on the plates, the silk coming out white and the cotton black.

Some exceedingly curious permanent illustrations of the phenomena are to be found. There are several impressions of brasses in the basement under Henry IV's chantry in Canterbury Cathedral. On the walls appear shapes of the effigies. Sometimes the stone is unstained all over the area of the figure but surrounded by a broad, dark smudge; and in other cases the reverse is found, the area of the figures being indicated by a uniform dark tint, while the surrounding stone is unstained. Friends of Mr. Croft, who can be trusted for their authentic evidence, give two remarkably interesting cases of breath figures of this permanent description. The plate glass window of a hotel in London has on the inside a screen of ground glass lying near, but not touching; upon the latter are the words "Coffee Room," in clear, unfrosted letters. When the screen was taken away the words were left plainly visible on the window, and no washing would remove them. A house in London had been a hotel three years before; on one of the windows had been a brown gauze blind, with the gilt letters "Coffee Room" on it. On misty days the words "Coffee Room" are distinctly seen, but not on other days. This is a marvelously accurate instance of permanent breath figures, the mist acting like the breath, depositing the moisture on the glass. There is no doubt that a little observation on the part of our readers would reveal many curiosities of this kind in old houses, or at railway stations.

No one, as yet, has clearly explained how these impressions are produced by electricity and heat. The fact always confronts us that the simpler the phenomena the more difficult is the explanation.—Knowledge.

THE IODINE VOLTAMETER.

MR. HERROUN read a paper recently on the above subject before the Physical Society, London.

After referring to the usual methods of determining the value of the small currents used in calibrating galvanometers and other apparatus for measuring small currents and discussing the errors to which they are subject, the author gave his reasons for selecting iodine. He did this since, with the exception of mercury in the mercurous state, iodine has the largest

electro-chemical equivalent, and, in addition, by titration with sodium thiosulphate, it is possible to determine the quantity of iodine liberated with a greater accuracy than can be obtained by weighing a deposit of copper or silver with the balance. The solution employed in the voltameter contains 10 to 15 per cent. of zinc iodide. If care is taken to leave a small piece of metallic zinc in this solution, no free iodine is liberated on keeping, unless the solution is exposed to a strong light for some time.

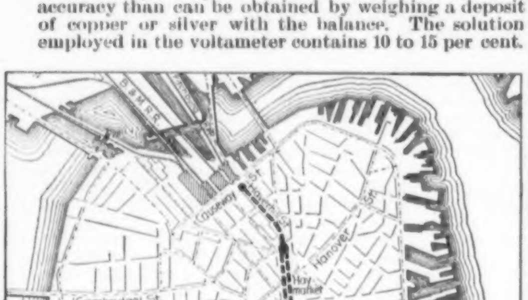
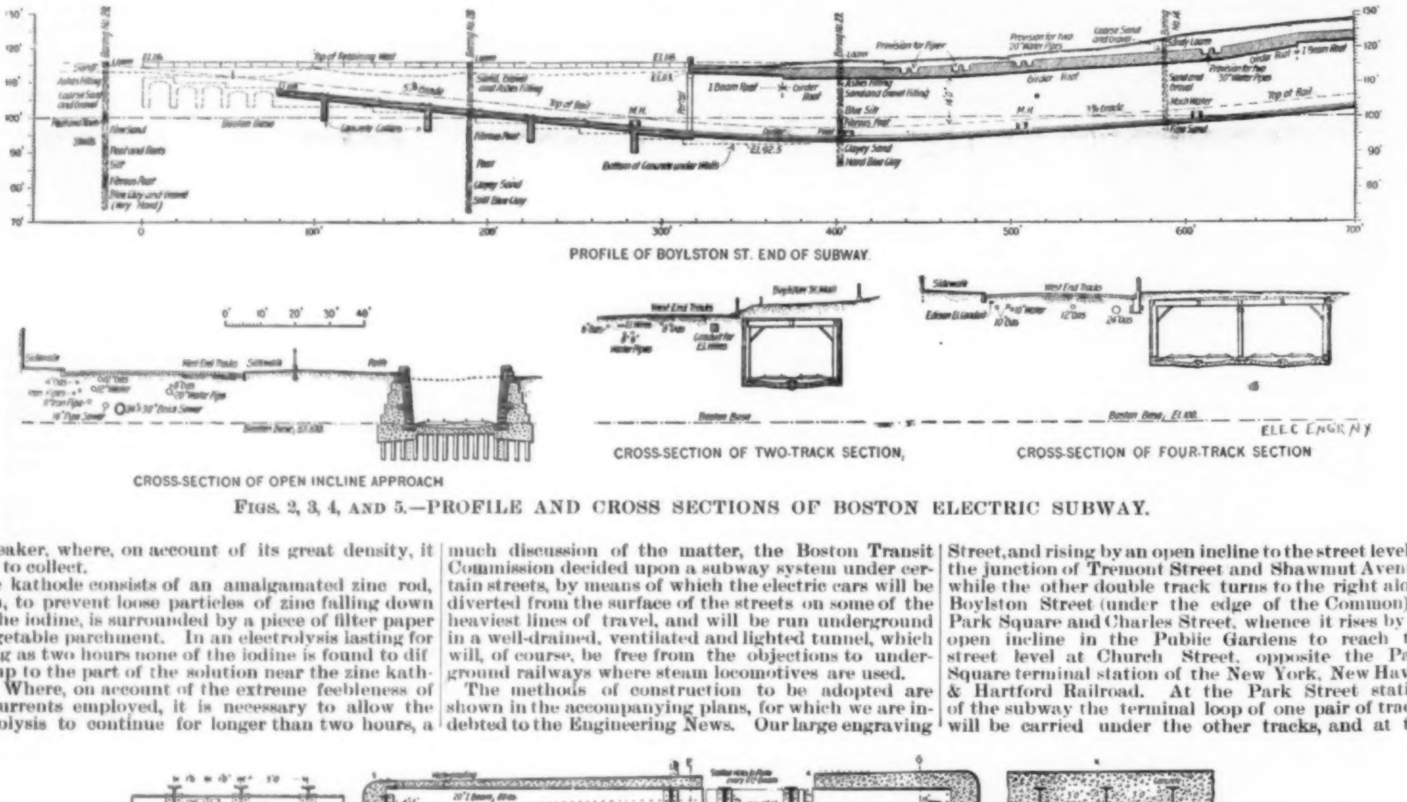


FIG. 1.—MAP SHOWING ROUTE OF BOSTON ELECTRIC SUBWAY.

The anode consists of a plate of platinum at the bottom of a tall and fairly narrow beaker. The wire leading the current to the anode is incased in a glass tube, so that the iodine is only liberated at the bottom of the beaker, where, on account of its great density, it tends to collect.

The kathode consists of an amalgamated zinc rod, which, to prevent loose particles of zinc falling down into the iodine, is surrounded by a piece of filter paper or vegetable parchment. In an electrolysis lasting for as long as two hours none of the iodine is found to diffuse up to the part of the solution near the zinc kathode. Where, on account of the extreme feebleness of the currents employed, it is necessary to allow the electrolysis to continue for longer than two hours, a U tube is used with two small plugs of asbestos at the bend, the anode being in one limb and the kathode in the other. With this form of voltameter, even after the current has flowed for several days, no signs of iodine have been found in the limb containing the kathode.



FIGS. 2, 3, 4, AND 5.—PROFILE AND CROSS SECTIONS OF BOSTON ELECTRIC SUBWAY.

On account of the production of electric convection currents, the iodine voltameter does not seem to be quite so suitable for the accurate measurement of strong currents.

After the current is stopped the zinc electrode is immediately removed, the solution stirred, and the amount of iodine liberated determined by titration with sodium thiosulphate. The author finds that a convenient strength of the thiosulphate solution is one in which 1 c. c. corresponds to the amount of iodine liberated by 5 coulombs of electricity. This solution contains 12·8375 grammes of pure crystallized sodium thiosulphate per liter. It is possible to perform the titration to within 0·1 c. c., which corresponds to 0·5 coulomb, or if the electrolysis lasted one hour to $\frac{1}{7200}$ ampere. In a comparison made with a silver voltameter, the current as deduced from the silver was 0·0264 ampere and that deduced from the iodine 0·0266. The author considers that part of the difference may be due to the effect of oxygen dissolved in the silver nitrate.

THE BOSTON ELECTRIC RAILWAY SUBWAY.

THE city of Boston has probably a greater number of radiating electric street railways than any other city in the United States, and it is noted far and wide for the extent of its street railway accommodations. The very extent of such accommodation, however, has developed a very serious difficulty—namely, that with numerous radial lines converging on a few streets at the center of the city, some of the busiest streets have such an enormous and continuous traffic of electric cars that vehicular traffic is seriously interfered with, while pedestrians find it difficult and dangerous to cross the streets. The trouble is all the more serious from the fact that many of the streets in the congested district are narrow and crooked, and have a considerable traffic of heavy wagons and carts. These conditions, among others, have led to various propositions for underground and elevated railways, none of which, however desirable as a means of providing additional rapid transit facilities, seemed at all likely to relieve the congestion of traffic of the streets in question. The problem was not one of providing rapid transit for a distance, but of facilitating traffic upon certain existing and stated routes within a very small area about one mile long and a quarter mile wide. After much discussion of the matter, the Boston Transit Commission decided upon a subway system under certain streets, by means of which the electric cars will be diverted from the surface of the streets on some of the heaviest lines of travel, and will be run underground in a well-drained, ventilated and lighted tunnel, which will, of course, be free from the objections to underground railways where steam locomotives are used.

The methods of construction to be adopted are shown in the accompanying plans, for which we are indebted to the Engineering News. Our large engraving shows the inside and outside of the subway as it will appear when finished.

As shown by the map, Fig. 1, the subway is to commence at an underground station in front of the new terminal station of the Boston & Maine Railroad at Causeway Street. The underground station has loop terminal tracks, and from the station two tracks extend along under Haverhill Street, while two surface tracks on this street, which connect with the various surface lines converging at this point, begin to descend an open incline approach at Travers Street, and reach the level of the other tracks at about Cross Street, where the four track section of the subway will commence, and a station with two island platforms will be built. The four-track subway will extend to near the commencement of Washington Street, where it will branch off into two double-track sections, one under Cornhill and the other under Brattle Street, which will converge again at a station under the open space at the junction of Tremont Street and Cornhill. From this station a double-track section will extend under Tremont Street to a station at Park Street, from which another four-track section will extend along Tremont Street (under the edge of the Boston Common) to a station at Boylston Street. From this station the lines diverge, one double-track subway continuing under Tremont Street to Hollis Street, and rising by an open incline to the street level at the junction of Tremont Street and Shawmut Avenue, while the other double track turns to the right along Boylston Street (under the edge of the Common) to Park Square and Charles Street, whence it rises by an open incline in the Public Gardens to reach the street level at Church Street, opposite the Park Square terminal station of the New York, New Haven & Hartford Railroad. At the Park Street station of the subway the terminal loop of one pair of tracks will be carried under the other tracks, and at the

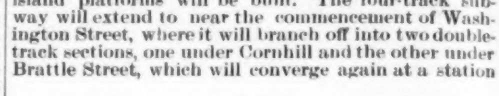


FIG. 7.—VENTILATING CHAMBER, BOSTON ELECTRIC SUBWAY.

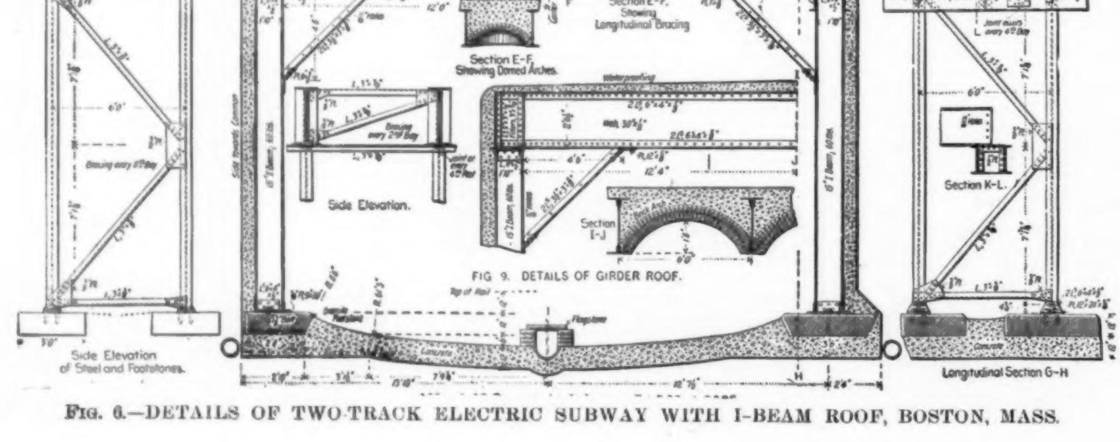


FIG. 6.—DETAILS OF TWO-TRACK ELECTRIC SUBWAY WITH I-BEAM ROOF, BOSTON, MASS.

Boylston Street station one of the Tremont Street tracks is to be carried under one of the Boylston Street tracks, which it crosses, thus avoiding all track crossings at grade. There will be about 5,600 ft. of double-track subway, and about 3,500 ft. of four-track subway. The tunnel will be ventilated by means of fans driven by electric motors, and will be brilliantly lighted by electricity. The section now under contract comprises the open incline from Church Street to Charles Street, the double-track subway under the Boylston Street mall of the Boston Common, and the four-track subway under the Tremont Street mall of the Common as far as a point opposite West Street. This is the route as adopted by the Boston Transit Commission, of which Mr. Howard A. Carson, M. Am. Soc. C.E., is chief engineer.

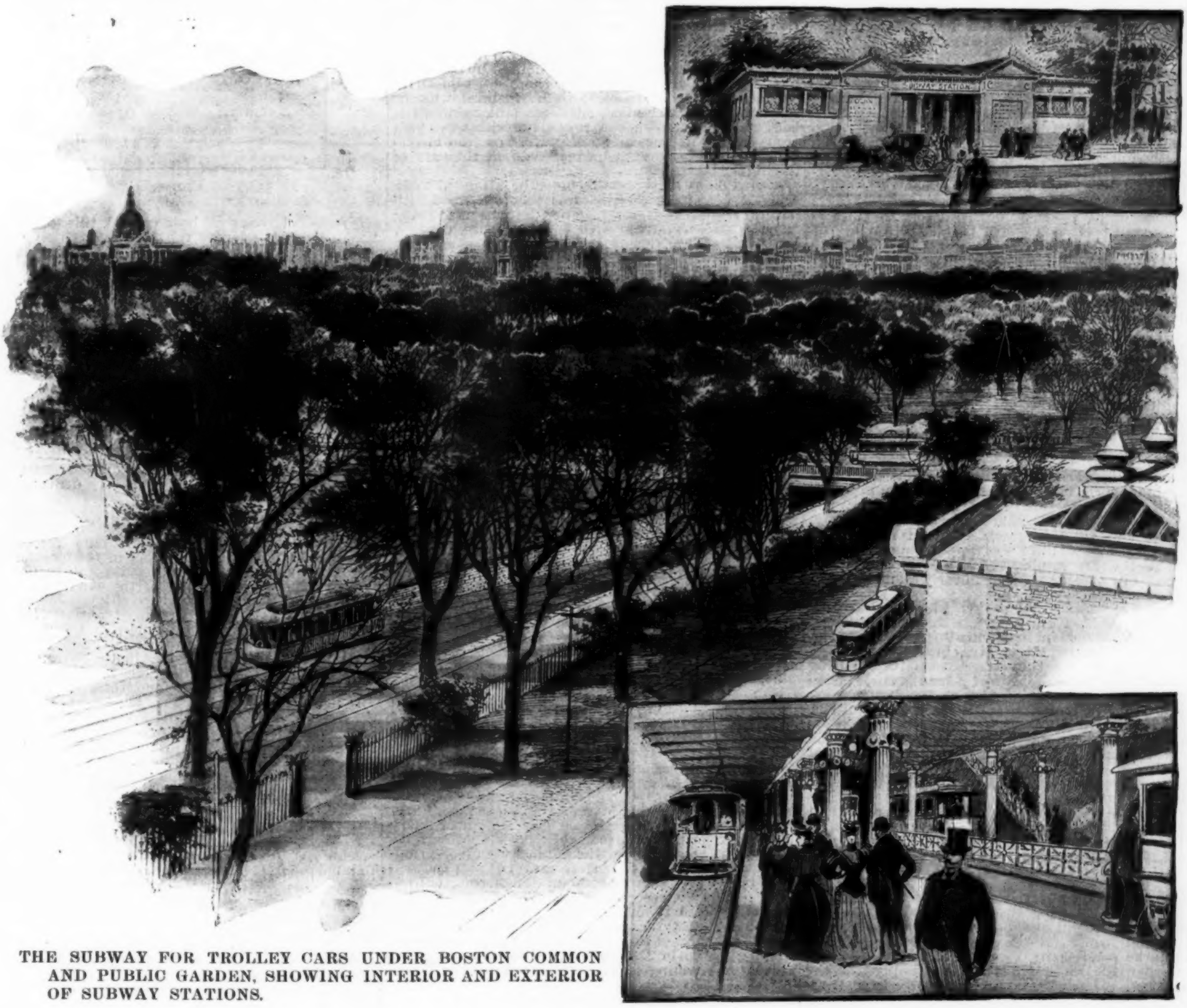
The profile of the subway is shown in Fig. 2. The grades are 3 per cent. and 5 per cent., and changes of direction are made by curves of 700 feet radius on the center line. Vertical curves connect the grades.

In general, the construction will consist of a concrete invert, side walls of steel columns with concrete filling between them, and a roof of plate girders or transverse I-beams, with brick jack arches between them and a covering of concrete. In the four-track section there will be a middle row of steel columns supporting the roof. In the open cuts of the approach inclines the retaining walls will be of concrete, with a facing of masonry in courses about 18 in. high and 24 in. thick, battering 1 in 12. The invert is also of concrete, and the invert and retaining walls of the inclines are to be founded on piles, with in some cases a grillage of 4 in. planks on transverse caps 10 by 10 in. The width at rail level is 24 ft. 1 in. to 24 ft. 8 in. These general sections are shown in Figs. 3, 4 and 5.

The cross section of the double-track subway with I-beam roof is shown in Fig. 6, the clear width between columns being 24 ft., and the clear height above rail level being 14 ft. The concrete invert is 12 in. thick, increased at the haunches, the upper surface having a radius of 61 ft. 3 in., ending in a radius of 8 ft. 6 in. at each side. The rail level is 2 ft. 6 in. above the bottom of the invert. Along the middle of the invert is a tile drain in the concrete, built up with sides of brick and a covering of flagstones, manholes being provided at intervals.

The ventilating chamber for the double-track section, shown in Fig. 7, is nearly opposite the public library, on Boylston Street. It is a concrete chamber about 13 ft. wide and 12 ft. long, with a 6 ft. opening into the tunnel fitted with a ventilating fan driven by an electric motor, the air exhausted being discharged through an air duct 6 ft. 6 in diameter. The ventilating chamber for the four-track section is near West Street, and is a segmental chamber having two fans in separate compartments drawing air from the tunnel through 6 ft. openings and discharging it through a duct 11 ft. 6 in. in diameter. The fans and motors will be furnished and put in place by the commission.

The contract for the iron and steel work has been awarded to the Pennsylvania Steel Company, of Steelton, Pa., and the contract for construction has been awarded to Jones & Meehan, of Jamaica Plain, Mass., at $136,602. The price for the iron and steel work is $39.32 per ton of 2,000 lb., and as about 1,000 tons will be required, the total price will be $39,320, making a grand total of $175,923 for this section of the work. The cost of the entire subway, exclusive of land damages, is estimated at about $4,000,000, and real estate and land damages are estimated to amount to about $1,000,000 more, or $5,000,000 in all.



THE SUBWAY FOR TROLLEY CARS UNDER BOSTON COMMON AND PUBLIC GARDEN, SHOWING INTERIOR AND EXTERIOR OF SUBWAY STATIONS.

BINOCULAR PHOTOMICROGRAPHY.

By Hon. A. A. ADEE, A.M.

As the photographic enthusiast cannot truthfully say that he has fathomed the deeper enjoyments of his art until he has invoked the aid of the stereoscopic camera, to fix in solid perspective and relief the scenes of travel and the character phases of the life around him, so the microscopic student falls short of one of the most valuable adjuncts to research who has not habitually employed the binocular and with its help seen his infinitely little world, bounded by its hither and nether walls of crystal, in perfect solidness, as though viewing its varied forms embedded in a block of ice like the fishes and flower wreaths sometimes displayed outside a restaurant or shop by way of advertising the wares within. It is much to the discredit of our students that so few binocular microscopes are made and sold in this country. In England they are constantly used, and by no other means can an equally positive idea be formed of the structure of the lower forms of infusorial and vegetable existence.

The principle of the binocular microscope is simple. It is easily demonstrable that the wide pencil of rays collected by an objective in close proximity to the object viewed comes aslant from all points except the axis of the field of view; that these slantwise rays come from different planes of the object; and that the objective, by getting very close to the object and squinting (so to speak) into and through it at various angles, forms a general impression of the whole which it projects along its optical axis up the body tube. If we stop down the angle of the objective, by a perforated diaphragm immediately behind it or by a perforated cap in front, the aperture of either being central, the axis of projection coincides with the optical axis of the lens system.

If, however, the aperture of this rear diaphragm or front cap be moved to one side, the lens still transmits a picture of the whole object, although the axis of projection is no longer central in a continuous right line, but eccentric, following the center of the aperture and bent slightly aside at that spot. A new point of view is in fact given to the objective, to one side or the other of the original axis, and its capacity for lateral and slantwise vision into the various planes of the object from this new view point is consequently increased. If now instead of an eccentered circular stop a half moon aperture be placed either behind or in front, the result is the same, the axis of incidence and projection being correspondingly displaced. When this half moon stop is so arranged as to cover up first one lateral semicircle and then the other, the image is seen under different angles of obliquity, much as when a solid object of larger size is looked at with the right and left eye alternately closed.

This refractive property of the objective is utilized in the binocular microscope by placing a prism close to the back glass, so as to cut the field in two and project half of the image-forming pencil slantwise across the main beam, and up a second tube fixed beside the body tube. Each eye thus receives an image of the whole object, but formed at a different angle, and the combination of the two by the unconscious habit of normal vision produces a true stereoscopic impression. Were each tube of the binocular prolonged and a camera attached, two pictures could be taken, each representing the object as seen by the respective eye, and the blending of the two by means of a stereoscope would give the illusion of dual vision.

The same result can be more simply attained by using the ordinary monocular tube and camera, covering up alternate semicircles at the back or front of the objective, and taking two successive negatives of the subject. This method has been often practiced with fairly good results when moderately low powers are used. One of the earliest practical experimenters in this field, Dr. William C. Borden, of the United States Army, contributed a paper to the American Microscopical Journal (vol. xiv, 1893, p. 329), in which he described this way of obtaining stereoscopic photomicrographs, and detailed the conditions necessary to success, and the difficulties in the way of realizing them.

The chief obstacle is the almost impossibility of getting a perfectly uniform illumination of the field which shall subsist unchanged when the semicircular diaphragm is shifted. It is easy to obtain an even disk with either half aperture, but on making the change the other half commonly shows up in partial shadow, and sometimes as a background effect with the object standing out whitely illuminated. Only a very small field can be evenly lighted. Altering the illumination brings a host of diffraction phenomena into effect, so that the identity of the optical images is lost. Again, this method is only capable of exact application with medium powers, for it is demonstrable that each alter-

nate half of the projected image-forming pencil shows the subject as the objective sees it at close range, that is, under oblique illumination from opposite sides.

Very simple observation will satisfy any one that oblique illumination alters the apparent position of points in different planes, and that this distortion increases with the shorter focus and wider aperture of the higher powers. A fine filament or speck, not in perfect focus under a one-fifth lens, may be made to shift its position well across the field of view by altering the oblique illumination from left to right. It thus stands to reason that if the two pictures so obtained be stereoscopically combined, the result is genuine binocular vision by refraction, plus an exaggerated displacement of the different planes due to diffraction.

Dr. Borden seems to have warily discerned these stumbling blocks and turned his attention to other methods of obtaining binocular photographs of microscopic subjects under unchanged conditions of central illumination and with unimpaired performance of the objective. The purpose being to imitate the human eye as closely as possible in its way of doing business, that is, to get two views of the same object under identical circumstances, but from points laterally separated by a space equivalent, so far as the effect is concerned, to the distance that ordinarily separates the pupils of the eyes, he adopted the expedient of tilting the object on the stage of the microscope, and this he rightly calls "the one preferably to be adopted whenever practicable." Looking downward at a plane object lying perpendicularly under the nose, it is clear that the right eye sees it as though it were tilted slightly to the left, and the left eye sees it with an equal tilt in the opposite direction. When the object itself is physically tilted on the stage, the solitary cyclops eye of the microscope sees it alternately from the points where its right and left eyes would be if it had them.

This mechanical way of obtaining binocular vision is essentially dioptric, and so, wholly different from the method of the Wenham prism, which depends on the refractive, and to some extent diffractive, properties of the microscopic objective, which does something the eye never dreamed of doing by collecting a wide cone of rays from an object at very short range and projecting it as a nearly parallel beam up the body tube. Could the tilting system be broken into steady work, its results would be almost entirely independent of the optical idiosyncrasies of the lens and afford a fairly satisfactory means of viewing the magnified object in its true binocular aspects.

I have not had the good fortune to get sight of the mechanical device by which Dr. Borden tilts his slide and takes his views. As he speaks of "focusing after tilting the slide," I infer that some necessary readjustment follows the taking of the first picture in order to get the object properly centered if the tilt has disturbed its position, and to get a fresh focus as nearly as possible identical with that of the first position.

Whatever his way of working, his results have attracted much attention in the microscopical world, and that grave body, the Royal Microscopical Society, of London, discussed them in a meeting reported in the Journal for April, 1894, and recorded its admiration of a fine stereoscopic picture of an injected section of the muscle of a cat, of which I am happy to possess a copy, thanks to the doctor's kindness. There is no question that the stereoscopic illusion is properly and strikingly rendered—the tiny capillaries are seen interlaced and superposed in a transparent bed nearly an inch in apparent thickness.

Moved by a natural emulation, I hastened to essay the system pointed out by Dr. Borden, after having tried and abandoned an ingenious little device, a sliding shutter behind the objective, intended to reach binocular effects by the diffractive path. Setting one margin of the slide against a transverse ledge on the microscope stage, a bit of cork 1-16th inch thick set under the other margin supplied the needful tilt. The difficulties of adjustment for the alternate views soon became apparent, and especially the botheration of getting a new focus even approximately identical with the first.

My results were encouraging, in that they were almost, but not quite, stereoscopic. I soon became convinced that some mechanical device was required which should work automatically, so that the second view could be taken without alteration of the focus or any other permanent conditions. I reasoned that the axis of "tiltation" must run up and down the center of the photographic field, exactly bisecting it, and that it must furthermore lie wholly in the plane of the object, so that when the slide was tilted a focused point in the central meridian would still remain central and in focus. These conditions being fulfilled, it would be possible, in theory, after taking the first view from the right eye point, to simply tilt the slide, insert a fresh plate, and make the second exposure without renewed examination.

It does, in fact, so work in practice, although the tilting stage I have devised and built is not as solid in construction nor as accurate in its alignments as it will doubtless be when some professional microscope maker works out the design in enduring brass and steel. Briefly, it consists of a circular stage 3½ inches in diameter, mounted on two pivots, the axis of which passes through its under plane. A generous central opening and spring clips on its under side permit the slide to be secured thereon face upward, thus achieving the most essential condition of having the axis of oscillation lie in the superior plane of the slide, or rather a few microns above it, so as to traverse the center of an ordinarily thin section or other subject.

This tilting stage works in raised bearings on a plate which clamps firmly to the stage of the microscope, the axis of the bearings being perpendicular to the field of view. By removing the tilting stage and stretching a fine thread between the bearings, the axis of oscillation is focused on the thread and centered in the field so as to exactly bisect it. When the slide is adjusted on the tilting stage and the latter set in its pivotal bearings (the thread having, of course, been removed), the object is found to be closely in focus and a sharp definition on the central perpendicular zone is readily obtained. After this, tilting the stage to either side does not appreciably disturb the focus on the axial line.

The definition necessarily falls off a bit toward either side, but this does not impair the subsequent stereoscopic effect; for the indistinct part of one picture is sharper in the other if the focusing has been rightly managed, and, as Dr. Borden points out, "full relief and sharpness are obtained in the combined image, even if one of the pictures is blurred and indistinct," inasmuch as "the sharp outlines of the good picture will override the somewhat blurred outlines of the poorer one, while the combination of the two produces the impression of relief."

Two stop screws beneath the tilting stage on either side enable the amount of the tilt to be adjusted. The angle of the tilt is, curiously, much less than the angle at which the slide would be viewed by the right and left eye alternately at the normal distance of ten inches, which, with an average pair of eyes, is about 15°. The objective, on the contrary, sees the object at a distance of an inch or less, and moreover collects a visual cone of much wider angle. The result is that the angle of the tilt is exaggerated in projection, and the amount of inclination to be given to the slide seems to be governed directly by the angular aperture of the objective, and to a lesser degree by the focal distance at which the picture is photographed—that is, by the excess of amplification of the image over the initial magnification yielded by the objective at ten inches. I have not yet attempted to figure out the problem. By empirical trials I find that with a one inch objective of 0·20 numerical aperture, and a camera draw of 36 inches, the tilt should be between 3° and 4°, to give a natural relief under the stereoscope. With higher powers, or when a projection eyepiece is used to increase the amplification, the angle of tilt is less.

The utility of this mechanical process of obtaining binocular photographs is perforce limited by the working distance of the objective, for there must be space enough to allow the object to be inclined without smashing the cover glass, or, worse still, ruining the lens. I have taken encouraging views with a ⅛ of generous frontal distance and a Zeiss No. 4 projection eyepiece, but I have yet much to learn about this use of the higher powers.

A good many little details must be attended to in order to get satisfactory pictures that will blend with natural relief. It is, for instance, important to bring out the two negatives with equal printing density. Developing the plates in succession in the same bath involves two sources of inequality: the difficulty of arresting the process at the right moment, and the circumstance that the second development works slower and gives a trifle more contrast. This really doesn't make much difference, for the stereoscope is able to combine into fairly good illusiveness pictures of notable difference in depth and tone. But it is preferable to have them as much alike as possible. As to the negatives, I now accomplish this by developing two 4 by 5 plates side by side in an 8 by 10 tray, thus getting identical depth barring the slight difference due to the varying thickness of the emulsion film in plates from the same box. Even this slight discrepancy may be obviated when Carbutt's orthochromatic plates are used; for, as they are now packed, each folded pair forms practically one plate cut down the middle, and the separated halves may be taken for the paired negatives. Printing and toning ought also to be done in pairs under identical conditions and with the utmost care. In mounting the paired prints when no eyepiece has been used, the image is inverted as in an ordinary view camera, so that the right eye print goes on the left of the card, and vice versa. But when an eyepiece is employed the image is erected and the mounting order must be reversed.

After all, however, the most essential condition to success lies in the choice of the subject, which should be strongly marked in some such way as to naturally suggest perspective, and so eke out the stereoscopic illusion. A stereograph of an egg, for instance, is materially fortified by the knowledge that it is an egg, and it is astonishing how much the illusion is helped when one knows what he is to look for—a fact which, by the way, pervades the whole range of microscopical research. I have recently been made happy by hitting on a peculiarly suitable subject—the gizzard of the common house cricket. This singular organ is studded with horny finger-branched processes that stand up at a wide angle from the basal membrane. Their saliency is recognizable even in an ordinary photomicrograph. One can but envy the digestive powers of a creature so well equipped with food-grinding appliances. That my stereograph of this remarkable object produces by combination of the dual images a true stereoscopic illusion is evident on the merest inspection; and it is, moreover, patent to the most casual observer that, as was remarked by a friend to whom I showed this print, such an animal ought to be capable of lasting through as many as three seasons of Washington dinners.—Photographic Times.

[Continued from SUPPLEMENT, 1016, page 16242.]

THE RARER METALS AND THEIR ALLOYS.*

Now turn to more complex curves taken on one plate by making the sensitized photographic plate seize the critical part of the curve, the range of the swing of the mirror from hot to cold being some sixty feet. The upper curve (Fig. 4) gives the freezing point of bismuth, and you see that surfusion, a, is clearly marked, the temperature at which bismuth freezes being 268°. The lower point represents the freezing point of tin, which we know is 231° C., and in it surfusion, b, is also clearly marked. The lowest curve of all contains a subordinate point in the cooling curve of standard gold, and this subordinate point, c, which you will observe is lower than the freezing point of tin, is caused by the falling out of solution of a small portion of bismuth, which alloyed itself with some gold atoms, and "fell out" below the freezing point not only of bismuth itself but of tin. Now gold with a low freezing point in it like this is found to be very brittle, and we are in a fair way to answer the question why $\frac{2}{10}$ per cent. of zirconium doubles the strength of gold, while $\frac{2}{10}$ per cent. of thallium, another rare metal, halves the strength. In the case of the zirconium the subordinate point is very high up, while in the case of the thallium it is very low down. So far as my

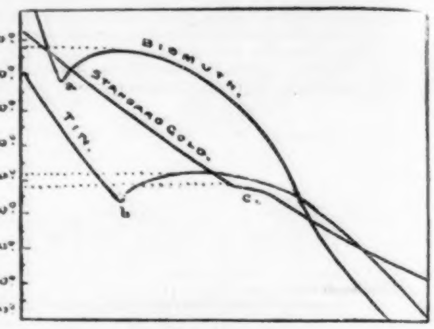


FIG. 4.

experiments have as yet been carried, this seems to be a fact which underlies the whole question of the strength of metals and alloys. If the subordinate point is low, the metal will be weak; if it is high in relation to the main setting point, then the metal will be strong, and the conclusion of the whole matter is this: The rarer metals which demand for their isolation from their oxides either the use of aluminum or the electric arc, never, so far as I can ascertain, produce low freezing points when they are added in small quantities to those metals which are used for constructive purposes. The difficultly fusible rarer metals are never the cause of weakness, but always confer some property which is precious in industrial use. How these rarer metals act, why the small quantities of the added rare metals permeate the molecules, or, it may be the atoms and strengthen the metallic mass, we do not know; we are only gradually accumulating evidence which is afforded by this very delicate physiological method of investigation.

As regards the actual temperatures represented by points on such curves, it will be remembered that the indications afforded by the recording pyrometer are only relative, and that gold is one of the most suitable metals for enabling a high, fixed point to be determined. There is much trustworthy evidence in favor of the adoption of 1045° as the melting point hitherto accepted for gold. The results of recent work indicate, however, that this is too low, and it may prove to be as high as 1061·7°, which is the melting point given by Heycock and Neville* in the latest of their admirable series of investigations to which reference was made in my Friday evening lecture of 1891.

It may be well to point to a few instances in which the industrial use of such of the rarer metals as have been available in sufficient quantity is made evident. Modern developments in armor plate and projectiles will occur to many of us at once. This diagram (Fig. 5) affords a rapid view of the progress which has been made, and in collecting the materials for it from various sources, I have been aided by Mr. Jenkins. The effect of projectiles of approximately the same weight, when fired with the same velocity against six-inch plates, enables comparative results to be studied, and illustrates the fact that the rivalry between artillerists who design guns and metallurgists who attempt to produce both impenetrable armor plates and irresistible projectiles forms one of the most interesting pages in our national history. When metallic armor was first applied to the sides of war vessels, it was of wrought iron, and proved to be of very great service by absolutely preventing the passage of ordinary cast iron shot into the interior of the vessel, as was demonstrated during the American civil war in 1861. It was found to be necessary, in order to pierce the plates, to employ harder and larger projectiles than those then in use, and the chilled cast iron shot with which Colonel Palliser's name is identified proved to be formidable and effective. The point of such a projectile was sufficiently hard to retain its form under impact with the plate, and it was only necessary to

* A Friday evening discourse, delivered at the Royal Institution on March 15, by Professor Roberts-Austen, C.B., F.R.S.—From Nature.

* Trans. Chem. Soc., vol. lxvii, 1895, p. 160.

ATTACK OF 6 INCH ARMOR PLATES BY 4·72 INCH SHELLS, WEIGHING 57·2 LB.

Wrought iron. 1868. | Compound plate. 1888. | Steel. 1888. | Steel. 1894. | Nickel-steel. 1894. | Harveyed nickel-steel. 1894.

FIG. 5.—The upper series of projectiles are Palliser chilled iron shells, and the lower are chrome steel. In each case the velocity of the projectile is approximately 1,640 foot-seconds, and the energy 1,070 foot-tons.

impart a moderate velocity to a shot to enable it to pass through the wrought iron armor (A, Fig. 5).

It soon became evident that in order to resist the attack of such projectiles with a plate of any reasonable thickness, it would be necessary to make the plate harder, so that the point of the projectile should be damaged at the moment of first contact, and the reaction to the blow distributed over a considerable area of the plate. This object could be attained by either using a steel plate in a more or less hardened condition or by employing a plate with a very hard face of steel, and a less hard but tougher back. The authorities in this country, during the decade 1880–90, had a very high opinion of plates that resisted attack without the development of through cracks, and this led to the production of the compound plate. The backs of these plates (B, Fig. 5) are of wrought iron, the fronts are of a more or less hard variety of steel, either cast on or welded on, by a layer of steel of an intermediate quality cast between the two plates. Armor plates of this kind differ in detail, but the principle of their construction is now generally accepted as correct.

Such plates shown by plate B resisted the attack of large Palliser shells admirably, as when such shells struck the plate they were damaged at their points, and the remainder of the shell was unable to perforate the armor against which it was directed. An increase in the size of the projectiles led, however, to a decrease in the resisting power of the plates, portions of the hard face of which would at times be detached in flakes from the junction of the steel and the iron. An increase in the toughness of the projectiles by a substitution of forged chrome-steel for chilled iron (see lower part of plate B) secured a victory for the shot, which was then enabled to impart its energy to the plate faster than the surface of the plate itself could transmit the energy to the back. The result was that the plate was overcome, as it were, piecemeal; the steel surface was not sufficient to resist the blow itself, and was shattered, leaving the projectile an easy victory over the soft back. The lower part of plate B (in Fig. 5) represents a similar plate to that used in the Nettle trials of 1888.* It must not be forgotten in this connection that the armor of a ship is but little likely to be struck twice by heavy projectiles in the same place, although it might be by smaller ones.

Plates made entirely of steel, on the other hand, were found, prior to 1888, to have a considerable tendency to break up completely when struck by the shot. It was not possible, on that account, to make their faces as hard as those of compound plates; but while they did not resist the Palliser shot nearly so well as the rival compound plate, they offered more effective resistance to steel shot (see lower part of plate C, Fig. 5).

It appears that Berthier recognized, in 1820, the great value of chromium when alloyed with iron; but its use for projectiles, although now general, is of comparatively recent date, and these projectiles now commonly contain from 1·2 to 1·5 per cent. of chromium, and will hold together even when they strike steel plates at a velocity of 2,000 feet per second† (see lower part of plate D), and unless the armor plate is of considerable thickness, such projectiles will even carry bursting charges of explosives through it. [The behavior of a chromium-steel shell, made by Mr. Hadfield, was dwelt upon, and the shell was exhibited.]

It now remained to be seen what could be done in the way of toughening and hardening the plates, so as to resist the chrome-steel shot. About the year 1888, very great improvements were made in the production of steel plates. Devices for hardening and tempering plates were ultimately obtained, so that the latter were hard enough throughout their substance to give them the necessary resisting power without such serious cracking as had occurred in previous ones. But in 1889, Mr. Riley exhibited, at the meeting of the Iron and Steel Institute, a thin plate that owed its remarkable toughness to the presence of nickel in the steel. The immediate result of this was that plates could be made to contain more carbon, and hence be harder, without at the same time having increased brittleness; such plates, indeed, could be water-hardened and yet not crack.

The plate, E (Fig. 5), represents the behavior of nickel-steel armor. It will be seen that it is penetrated to a much less extent than in the former case; at the same time there is entire absence of cracking.

Now as to the hardening processes. Evrard had developed the use of the lead bath in France, while Capt. Tressider‡ had perfected the use of the water jet in England for the purpose of rapidly cooling the heated plates. The principle adopted in the design of the compound plates has been again utilized by Harvey, who places the soft steel or nickel-steel plate in a furnace of suitable construction, and covers it with carbonaceous material such as charcoal, and strongly heats it for a period which may be as long as 120 hours. This is the old Sheffield process of cementation, and the result is to increase the carbon from 0·35 per cent. in the body of the plate to 0·6 per cent. or even more at the front surface, the increase in the amount of carbon only extending to a depth of two or three inches in the thickest armor.

The carbonized face is then "chill-hardened," the result being that the best chrome-steel shot are shattered at the moment of impact, unless they are of very large size as compared with the thickness of the plate. The interesting result was observed lately§ of shot doing less harm to the plate, and penetrating less, when its velocity was increased beyond a certain value, a result due to a superiority in the power of the face of the plate to transmit energy over that possessed by the projectile, which was itself damaged, when a certain rate was exceeded. At a comparatively low velocity, the point of the shot would resist fracture, but the energy of the projectile is not then sufficient to perforate the plate, which would need the attack of a much larger gun firing a projectile at a lower velocity.

The tendency to-day is to dispense with nickel and to use ordinary steel, "Harveyed;"* this gives excellent six-inch plates, but there is some difference of opinion as to whether it is advantageous to omit nickel in the case of very thick plates, and the problem is now being worked out by the method of trial. Probably, too, the Harveyed plates will be much improved by judicious forging after the process, as is indicated by some recent work done in America. The use of chromium in the plates may lead to interesting results.

Turn for a moment to the Majestic class of ships, the construction of which we owe to the genius of Sir William White, to whom I am indebted for a section representing the exact size of the protection afforded to the barbette of the Majestic. [This section was exhibited and is shown as reduced to the diagram, Fig. 6.] Her armor is of the Harveyed steel, which has

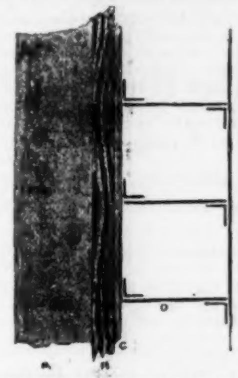


FIG. 6.—Section of Barbette of the Majestic.

hitherto proved singularly resisting to chromium projectiles.

In this section, A represents a 14-inch Harveyed steel armor plate; B, a 4 inch teak backing; C, a $1\frac{1}{4}$-inch steel plate; D, $\frac{1}{2}$-inch steel frames; and E, $\frac{1}{2}$-inch steel linings.

It will, I trust, have been evident that two of the rarer metals, chromium and nickel, are playing a very important part in our national defenses; and if I ever lecture to you again, it may be possible for me to record similar triumphs for molybdenum, titanium, vanadium and others of these still rarer metals.

Here is another alloy, for which I am indebted to Mr. Hadfield. It is iron alloyed with 25 per cent. of nickel, and Hopkinson has shown that its density is permanently reduced by two per cent. by an exposure to a temperature of —80°, that is, the metal expands at this temperature.

Supposing, therefore, that a ship-of-war was built in our climate of ordinary steel and clad with some three thousand tons of such nickel-steel armor, we are confronted with the extraordinary fact that if such a ship visited the Arctic regions, it would actually become some two feet longer, and the shearing which would result from the expansion of the armor by exposure to cold would destroy the ship. Before I leave the question of the nickel-iron alloys, let me direct your attention to this triple alloy of iron, nickel and cobalt in simple atomic proportions. Dr. Oliver Lodge believes that this alloy will be found to possess very remarkable properties; in fact, as he told me, if nature had properly understood Mendeleef, this alloy would really have been an element. As regards electrical properties of alloys, it is impossible to say what services the rarer metals may not render; and I would remind you that "platinoid," mainly a nickel-copper alloy, owes to the presence of a little tungsten its peculiar property of having a high electrical resistance which does not change with temperature.

One other instance of the kind of influence the rarer metals may be expected to exert is all that time will permit me to give you. It relates to their influence on aluminum itself. You have heard much of the adoption of aluminum in such branches of naval construction as demand lightness and portability. During last autumn Messrs. Yarrow completed a torpedo boat which was built of aluminum alloyed with 6 per cent. of copper. Her hull is 50 per cent. lighter, and she is $3\frac{1}{4}$ knots faster than a similar boat of steel would have been, and, notwithstanding her increased speed, is singularly free from vibration.

FIG. 7.—Half-section Midship of Aluminum Torpedo Boat.

Her plates are $\frac{1}{16}$ inch thick and $\frac{1}{4}$ inch where greater strength is needed. It remains to be seen whether copper is the best metal to alloy with aluminum. Several of the rarer metals have already been tried, and among them titanium. Two per cent. of this rare metal seems to confer remarkable properties on aluminum, and it should do so according to the views I have expressed, for the cooling curve of the titanium-aluminum alloy would certainly show a high subordinate freezing point.

Hitherto I have appealed to industrial work, rather than to abstract science, for illustrations of the services which the rarer metals may render. One reason for this is that at present we have but little knowledge of some of the rarer metals apart from their association with carbon. The metals yielded by treatment of oxides in the electric arc are always carbides. There are, in fact, some of the rarer metals which we, as yet, can hardly be said to know except as carbides. As the following experiment is the last of the series, I would express my thanks to my assistant, Mr. Stansfield, for the great care he has bestowed in order to insure their success. Here is the carbide of calcium which is produced by heating lime and carbon in the electric arc. It possesses great chemical activity, for if it is placed in water the calcium seizes the oxygen of the water, while the carbon also combines with the hydrogen, and acetylene is the result, which burns brilliantly. [Experiment shown.] If the carbide of calcium be placed in chlorine water, evil-smelling chloride of carbon is formed.

In studying the relations of the rarer metals to iron, it is impossible to dissociate them from the influence exerted by the simultaneous presence of carbon; but carbon is a protean element—it may be dissolved in iron, or it may exist in iron in any of the varied forms in which we know it when it is free. Matthiessen, the great authority on alloys, actually writes of the "carbon-iron alloys." I do not hesitate, therefore, on the ground that the subject might appear to be without the limits of the title of this lecture, to point to one other result which has been achieved by M. Moissan. Here is a fragment of pig iron highly carburized: melt it in the electric arc in the presence of carbon, and cool the molten metal suddenly, preferably by plunging it into molten lead. As cast iron expands on solidification, the little mass will become solid at its surface and will contract; but when, in turn, the still fluid mass in the interior cools, it expands against the solid crust, and consequently solidifies under very great pressure. Dissolve such a mass of carburized iron in nitric acid, to which chlorate of potash is added; treat the residue with caustic potash, submit it to the prolonged attack of hydrofluoric acid, then to boiling sulphuric acid, and finally fuse it with potash, to remove any traces of carbide of silicon, and you have carbon left, but—in the form of diamonds.

If you will not expect to see too much, I will show you some diamonds I have prepared by strictly following the directions of M. Moissan. As he points out, these diamonds, being produced under stress, are not entirely without action on polarized light, and they have, sometimes, the singular property of flying to pieces, like Rupert's drops, when they are mounted as preparations for the microscope. [The images of many small specimens were projected on the screen from the microscope, and Fig. 8, E, shows a sketch of one of

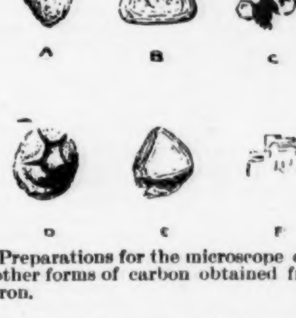


FIG. 8.—Preparations for the microscope of diamonds and other forms of carbon obtained from carburized iron.

these. The largest diamond yet produced by M. Moissan is 0·5 millimeter in diameter.]

A (Fig. 8) represents the rounded, pitted surface of a diamond, and B a crystal of diamond from the series prepared by M. Moissan, drawings of which illustrate his paper.* The rest of the specimens, C to F, were obtained by myself by the aid of his method, as above described. C represents a dendritic growth apparently composed of hexagonal plates of graphite, while D is a specimen of much interest, as it appears to be a hollow sphere of graphitic carbon, partially crushed in. Such examples are very numerous, and their surfaces are covered with minute round graphitic pits and prominences of great brilliancy. Specimen E (which, as already stated, was one of a series shown to the audience) is a broken crystal, probably a tetrahedron, and is the best crystallized specimen of diamond I have as yet succeeded in preparing. Minute diamonds, similar to A, may be readily produced, and brilliant fragments, with the lamella structure shown in F, are also often met with.

The close association of the rarer metals and carbon and their intimate relations with carbon, when they are hidden with it in iron, enabled me to refer to the production of the diamond and afford a basis for the few observations I would offer in conclusion. These relate to the singular attitude toward metallurgical research maintained by those who are in a position to promote the advancement of science in this country. Statements respecting the change of shining graphite into brilliant diamond are received with appreciative interest; but, on the other hand, the vast importance of effecting similar molecular changes in metals is ignored.

We may acknowledge that "no nation of modern times has done so much practical work in the world as ourselves, none has applied itself so conspicuously or with such conspicuous success to the indefatigable pursuit of all those branches of human knowledge which give to man his mastery over matter."† But it is typical of our peculiar British method of advance

* Proceedings Institution of Civil Engineers, 1889, vol. xcviii, p. 1, et seq.
† Journal U. S. Artillery, 1893, vol. ii, p. 497.
‡ Weaver, "Notes on Armor."—Journal U. S. Artillery, vol. iii, 1894, p. 417.
§ Brassey's Naval Annual, 1894, p. 367.

* Engineering, vol. lvii., 1894, pp. 465, 530, 595.

* Comptes Rendus, vol. cxviii, 1894 p. 324.
† The Times, February 22, 1895.

to dismiss all metallurgical questions as "industrial," and leave their consideration to private enterprise.

We are, fortunately, to spend, I believe, eighteen millions this year on our navy, and yet the nation only endows experimental research in all branches of science with four thousand pounds. We rightly and gladly spend a million on the Magnificent, and then stand by while manufacturers compete for the privilege of providing her with the armor plate which is to save her from disablement or destruction. We, as a nation, are fully holding our own in metallurgical progress, but we might be doing so much more. Why are so few workers studying the rarer metals and their alloys? Why is the crucible so often abandoned for the test tube? Is not the investigation of the properties of alloys precious for its own sake, or is our faith in the fruitfulness of the results of metallurgical investigation so weak that, in its case, the substance of things hoped for remains unsought for and unseen in the depths of obscurity in which metals are still left?

We must go back to the traditions of Faraday, who was the first to investigate the influence of the rarer metals upon iron, and to prepare the nickel-iron series of which so much has since been heard. He did not despise research, which might possibly tend to useful results, but joyously records his satisfaction at the fact that a generous gift from Wollaston of certain of the "scarce and more valuable metals" enabled him to transfer his experiments from the laboratory in Albemarle Street to the works of a manufacturer at Sheffield.

Faraday not only began the research I am pleading for to-night, but he gave us the germ of the dynamo, by the aid of which, as we have seen, the rarer metals may be isolated. If it is a source of national pride that research should be endowed apart from the national expenditure, let us, while remembering our responsibilities, rest in the hope that metallurgy will be well represented in the laboratory which private munificence is to place side by side with our historic Royal Institution.

THE ACTION OF LIGHT ON ANIMAL LIFE.*

ALTHOUGH a number of investigations have been made on the action of light on bacteria, very few experiments have been carried out to ascertain how direct insolation affects animals inoculated with particular disease microbes. Does exposure to sunshine increase or diminish an animal's susceptibility to disease? De Renzi was, we believe, the first to study this question experimentally, and he endeavored to answer it as regards tuberculosis by inoculating guinea pigs with tuberculous material. Some of the animals he kept in glass boxes exposed to the direct rays of the sun for five or six hours daily, while others were placed in the sunshine, but instead of glass, wooden boxes were used. De Renzi found that, while the guinea pigs in glass boxes—to which, therefore, the maximum amount of sunshine had access—died after 24, 39, 52 and 89 days, those in the opaque wooden boxes died after 20, 25, 26 and 41 days. Thus it would appear that sunshine materially assisted these animals in combating with tuberculous disease, for those individuals deprived of sunshine succumbed far more rapidly.

More recently, Dr. Masella has carried out a series of similar experiments with guinea pigs inoculated, however, with cholera and typhoid bacilli respectively. Various points were investigated as to whether insolation previous to inoculation increased the animal's susceptibility to these diseases, also what was the effect of insolation on the animal after infection, and whether the same results were obtained when the temperature of the surrounding air during insolation was not permitted to rise. The toxic properties of the cholera and typhoid broth cultures employed were carefully tested, and it was ascertained that the lethal dose in the case of cholera, procuring death in twenty-four hours, was secured by employing cultures in the proportion of 0·20 per cent. of the weight of the animal operated upon, while to obtain similar results with typhoid cultures, 0·40 per cent. of the weight of the animal was the proportion in which they had to be used.

In the case of both cholera and typhoid it was found that previous exposure to sunshine increased the animals' susceptibility to these diseases, for not only did they die more rapidly when subsequently inoculated with these cultures than the guinea pigs similarly treated, exposed, however, only to diffused light, but they succumbed to smaller doses, and doses which did not prove fatal to the guinea pigs which had been previously protected from sunshine. When the exposure to sunshine took place after infection fatal results were greatly accelerated, for instead of dying in from 15 to 24 hours, they succumbed in from 3 to 5 hours. These experiments were, however, open to the objection that the accelerated lethal action through subsequent insolation might be due to the higher temperature which necessarily prevailed in boxes exposed to sunshine over those to which diffused light only was admitted. To dispose of this difficulty, boxes were constructed with double cases through which a current of water was kept circulating; in the "sunshine" boxes, as before, only glass was used, while in the "diffused light" boxes the outer case was made of zinc. In spite, however, of these precautions as regards temperature, the results confirmed those previously obtained, the insolated animals still exhibiting the same increased susceptibility to infection from these diseases over the non-insolated animals.

Dr. Masella does not attempt to give any explanation of the remarkable results he has obtained, but we would suggest that the action of sunshine should be tried on antitoxines. It would be of great interest to ascertain how the potency of these protective fluids outside the body was affected by exposure to sunshine, and also what result, if any, insolation had on their generation within the animal system.

We know that the toxic properties of, for example, tetanus cultures may be entirely destroyed in from 15 to 18 hours in direct sunshine at a temperature of from 35° to 48° C., and Roux and Yersin state that five hours' direct insolation greatly modifies the toxic properties of diphtheria cultures; again, Calmette has found that after two weeks' insolation the poison of the Naya tripudians is completely destroyed, while a similar exposure has a damaging effect on the poison of the rattlesnake. So far as we are aware, the action of sunshine on the immunizing properties of serum has not been investigated, and its study should prove of immense interest and importance.

The results obtained by De Renzi with tuberculous infection have a practical confirmation in the acknowledged benefit which patients suffering from tuberculosis derive from residence in places such as Davos, where the maximum amount of sunshine is secured. On the other hand, Dr. Masella's experiments leave us with an uncomfortable uncertainty as to the wisdom of basking in the sunshine. He would have us believe that his investigations explain the greater prevalence and virulence of typhoid and cholera (which he states as an accepted fact) in hot countries, where the sun shines with greater power and more continuously. After all, our smoke-laden atmosphere and dreary yellow fogs may be turned to account seemingly, and the London water companies may congratulate themselves that these two water-borne diseases, par excellence, may be made to yield not only to efficient purifying processes at their hands, but that such an unexpected ally, according to Dr. Masella, is to be found in the limited amount of sunshine which Londoners can enjoy! G. C. FRANKLAND.

* From Nature.

CORUNDUM DEPOSITS OF GEORGIA.*

THE corundum deposits occur in a belt in the fully crystalline rocks which enter the State of Georgia from the southwestern corner of North Carolina and the northwest side of Carolina and pass through Alabama about midway of the Georgia boundary, having their line of strike toward the southwest at about an average of 35 or 40° west of south. The dip is sometimes vertical, but generally sharply inclined toward the southeast. The rocks making up the formations in this crystalline area belong to eight distinct types. Three of these, limestone, quartzite and slate, are plastics. The granite, gneiss and schists overlapping these plastics are completely crystalline. The other two are presumably of eruptive origin and may be designated as peridotite and metamorphosed diorite or hornblende gneiss. Mr. Francis P. King, the assistant, who made this report, assigns the age of the rocks provisionally to the Algonkian period, but intimates that a more thorough examination may result in assigning a portion of the rocks in this area to the Archean. All the corundum deposits thus far observed in Georgia occur in basic magnesium rocks, whose type has been given as peridotite, including chrysolite, anthophyllite, serpentized chrysolites, schistose chlorite, and steatite or soapstone. The corundum occurs sometimes in veins having practically parallel walls, but usually in lenticular pockets. The matrix of these deposits differs not only in different but in the same locality. Four types have been noticed, viz., 1, lime-soda feldspar, with quartz and phlogopite; 2, lime-soda feldspar with actinolite; 3, a coarse-grained aggregate of lime-soda feldspar and a black hornblende. Margarite is sometimes present in place of the feldspar. 4. A massive vein made up of a light grass green amphibole, limestone feldspar and a little chlorite. All the varieties of corundum have been found in Georgia with the exception of emery, the principal being the non-transparent variety of the corundum species. In color, shades of red and light to dark blue are common, pink, gray and blue predominate, and these colors often occur in the same specimen. White corundum is rare and shades of yellow and brown have not been observed.

The localities in which the corundum deposits have been found and worked on a commercial scale are Rabun and Union County. In the former is located the Laurel Creek mine, discovered in the early seventies, in which operations were carried on spasmodically until 1893. About the time operations were abandoned because of a cave-in, it is claimed that at a depth of 130 feet a vein averaging 8 feet in width was being worked. Three types of rock are represented at Laurel Creek: 1, gneiss; 2, hornblende gneiss; 3, peridotite (chrysolite, with a little chromite. Chrysolite more or less serpentized, and associated with chromite. Anthophyllite). In Union County the Track Rock mine is located on the south side of Track Rock gap in the northeastern portion of the county. Development is confined to a tunnel which enters the magnesium from its eastern side, penetrating about 200 feet and branching out at several points. Preceding the financial troubles of 1893, several tons of corundum were cleaned and shipped to the mills of the owners, New York Corundum and Mining Company. The formation differs considerably from that of the Laurel Creek region, being apparently made up of talcose-chlorite schists to the complete exclusion of chrysolites. Among the rocks taken from this mine is a dark green, finely granular rock, which was supposed to be massive chlorite, but a thin section examined under the microscope shows it to be chrysolite which has undergone great alteration. These are the only two properties which have been worked on any extensive commercial scale in the State. Discoveries of this mineral have also been made in the following counties: Towns, Lumpkin, Habersham, Hall, Forsyth, Cobb, Paulding, Douglas, Troup and Walton. Discoveries have been reported at various times from other counties along this same belt, and such are mentioned in the Bulletin, but they are referred to as possessing but little commercial importance.

In the preparation of corundum it is necessary to free it from the accompanying gangue. For this purpose a crusher is used if the gangue is hard, and the material afterward washed in a series of sluice boxes or in a revolving washing cylinder. This method of washing was devised as an improvement over the former method by the Track Rock people. The cylinder is barrel shaped, about 10 feet long and 6 feet across the widest part. One end has an open neck attached to permit the shoveling in of the material while the cylinder is in motion. Into this end also a steady stream of water is introduced by means of a pipe. The opposite end of the cylinder is covered by a wire screen. A trap door permits the ready removal of the corundum unclean. The corundum at Track Rock mine, because of a hard zone of margarite around it, has to be treated in another machine, which contains two disks armed with lugs or teeth, which are revolved with great rapidity. The covering of the corundum is worn off completely. For final preparation for the market a further washing, followed by a series of crushings, siftings and sizings, is resorted to and the material graded as desired.

* Abstract of Report by State Geological Survey.

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